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Printing Telegraph Systems Applied to Message Traffic Handling

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Review of the Subject.—*Ever since the building of the first practical automatic telegraph instruments by Vail in America in 1837, and Wheatstone in England in 1841, an ever-increasing amount of the world's high-speed communication has been carried on by the printing telegraph. While these early machines were built primarily for the use of the European Government Telegraphs or the large American telegraph companies, the developments of the last few years have produced an instrument which is a practical working tool for the service of modern commercial and industrial enterprises.*

This paper discusses some of the economic principles which determine the applicability of the automatic printing telegraph to present-day communication problems. Examples are given of the application of this type of apparatus to modern business conditions and the fundamental fact is demonstrated that whenever speed is essential in communication, consideration should be given to the automatic printing telegraph.

The discussion is limited to those forms of light traffic load printing telegraph systems which have been developed particularly for linking together the departments of the factory, the terminal points of the railroad, the branches of the banking, the brokerage or the selling organization or the units of any other large corporation.

A description is then given of the principle of operation of three such systems, somewhat in detail, as there is very little literature on the subject.

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Object and Scope of the Paper

In transmitting intelligence from one point to another, the requirements of one case differ widely from those of other cases. Sometimes speed of service is the important item, while under certain other conditions speed may be sacrificed for the sake of economy, or perhaps both speed and economy may have to be sacrificed for some other consideration—for instance, the transmission of original documents.

To meet the needs of these different problems, various types of communication systems are now in operation and it is becoming more and more of a problem to choose the system that will best meet the requirements of a given case. The business executive instinctively turns to the systems he is used to, and in many instances does not take the time to find out what other methods of communication are available. Too often a messenger service is used where mechanical conveyors of some kind should be in operation, or additional telephones are pressed into service where a printing telegraph system might be installed to advantage. Perhaps one of the most direct causes of this condition is a lack of literature on the subject.

It is the object of this paper, therefore, to point out very briefly some of the advantages of a branch of the communication art which is not very well-known to the average business man or industrial plant engineer and to describe briefly the operation of a few systems in this class.

The systems referred to are automatic printing telegraph systems. These may be divided into two classes:

1. Heavy traffic load systems.
2. Light traffic load systems.

Where the traffic load is approximately 80 words per minute or over, the volume may be handled with heavy traffic load systems. Smaller loads do not, as a rule, warrant the installation of an elaborate heavy traffic load system, but may best be handled with light traffic load systems. Of course, such conditions as fluctuations in traffic, speed of service or other considerations may justify the installation of a heavy traffic load system in cases where the average traffic load is less than 80 words per minute, for instance, where the traffic often fluctuates far above normal and where speed of service is important. For a general discussion, however, the above division may be taken as applying to a majority of cases.

Heavy traffic load systems have been described in various other papers[1] presented before the Institute but very little mention has been made of the light traffic load system. The following discussion will therefore be limited to three light traffic load systems developed within the last five or six years, namely:

1. The Morkrum "green code" system.
2. The Western Electric "start stop" system.
3. The Kleinschmidt system.

Applications of Printing Telegraph Equipment to Commercial Conditions

The three most important savings effected with printing telegraph systems are savings of time, line wire and labor.

The distance between the sending and receiving station does not necessarily have to be as great for the sake of economy, as is often assumed. A printing telegraph system will often pay for itself by the saving of time alone. Take, for instance, a concern where orders are received at a central point, to be filled, part at one department and part at other departments in the same plant. Ordinarily such orders are sent to the first de-

To be presented at the 10th Midwinter Convention of the A. I. E. E., New York, N. Y., February 15-17, 1922.

1. John H. Bell, "Printing Telegraph Systems." A. I. E. E. Trans. Vol. XXXIX, Part 2, 1920.

partment where certain items are placed on a truck together with the orders. The truck is then sent to the next point, where additions are made, and so on until the truck passes through all stations involved. This method requires a considerable amount of time which may be saved by using a printing telegraph system. If a receiving set is installed in each department, that part of an order which applies to the first department may be sent by wire to the first department, and that part which applies to the second department may be sent to the second department, etc. All this may be done automatically while making out the invoice. In one operation, therefore, the invoice is made out and the order is sent to the proper sections of the plant. All departments receive their parts of the order at practically the same time, and each may therefore start work immediately without having to wait for the others. The items are then brought together in the shipping room where they are checked against the original order and sent out. This is one instance where the saving of valuable time justifies the installation of a light traffic load printing telegraph system.

To illustrate a condition where line wire may be saved, we may assume a problem where there is a need for rapid transmission of a fairly large volume of traffic from New York to Chicago. Let us consider that speed is an important factor, and that, during the busy hours, the traffic load is over 40 words per minute. If Morse operators were placed at each point, an average of between 30 and 40 words per minute would be the most that could be handled, and to handle the traffic two line wires would have to be leased. The cost of the wires with two Morse operators at each end would be approximately as follows:

Two leased wires (approximately)	$40,000 per year
Four Morse operators at $1800 per year	7,200 " "
	$47,200 " "

The installation of a light traffic load system makes the second line wire unnecessary. The annual charges under this arrangement would be approximately as follows:

One Leased wire (approximately)	$20,000 per year
Two Operators at $1200 per year	2,400 " "
*Two Maintenance men at $1800 per year	3,600 " "
Annual charges on equipment figuring a depreciation over a period of 8 years, interest, taxes, administration and repair parts (approximately)	1,000 " "
	$27,000 " "

*This figure is kept high for purposes of illustration. A still greater saving would be shown in an actual case, as the maintenance men would either be free most of the day to do other work, or would act as operators, thus wiping out the $2400 operator charge.

By using automatic equipment, the speed may be very materially increased at a saving of approximately $20,000 per year over what it would cost to increase the speed by adding additional Morse operators. This is an instance where a saving of line wire more than justifies the installation of a light traffic load printing telegraph system.

Perhaps the best illustration of how a saving of labor can be effected, by the installation of automatic equipment, is the case of press associations. At one time a well-known press association employed as many as 100 messengers to deliver news to various newspapers scattered throughout a city. Light traffic load printing telegraph systems are now giving these papers far better news service, and, by means of periodic inspections, just a few maintenance men keep the equipment in order. At each newspaper office a receiving set is installed, and one transmitting set at the central bureau sends news to all of the newspapers simultaneously. The editors at the various newspapers tear off the printed copy from time to time but, as paper is fed into the printers automatically, no other attention is necessary.

These are only a few of the cases where automatic equipment may be used to advantage. Many others might be mentioned. Line wire plays but a small part in the first example, and in the second example this system of communication will still prove advantageous even if no saving in labor is shown. In all three cases, however, speed is essential and automatic equipment offers a promising solution of the problem.

The system chosen must be capable of operating at rates of speed slightly higher than that required for handling the average traffic load. At first glance it might appear that to increase the speed of a set above the point where it can handle the traffic under normal conditions would be destructive to the machines. Such is not the case, however. With equipment designed for a range of between 40 and 80 words per minute, the wear is the same for every 1000 words printed, no matter whether that 1000 words is printed at a speed of 40 words per minute or 80 words per minute. On long or poor lines, speed is limited by the carrying capacity of the line, but for shorter distances the speed should be regulated, not from the standpoint of wear on the machines, but in accordance with the traffic load. It has even been found practical to speed up above the sending capacity of one operator and to employ two operators at the sending station during the busy hours.

Methods used in Common by Systems to be Described

All three of the systems to be described make use of the following basic methods:

Messages are first prepared as perforations in a paper tape by typists familiar with a standard typewriter keyboard and the tape is then fed through a

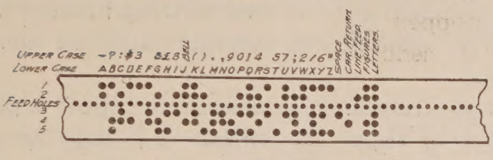
transmitter which translates the perforations into line signals and steps the tape forward one character at a time. At the other end of the wire the message is automatically received on a printer in page form.

Each system employs a different type of perforator but the perforated tape prepared by any one of them may be used on any of the three systems and also on the multiplex system used by the Western Union Telegraph Company.[2] Likewise each system employs a different type of printer but certain standards are adhered to so that any one of them may be used interchangeably with the printers used in the multiplex system.[2]

	1	2	3	4	5
A	−	−	+	+	+
B	−	+	+	−	−
C	+	−	−	−	+
D	−	+	+	−	+
E	−	+	+	+	+
F	−	+	−	−	+
G	+	−	+	−	−
H	+	+	−	+	−
I	+	−	−	+	+
J	−	−	+	−	+
K	−	−	−	−	+
L	+	−	+	+	−
M	+	+	−	−	−
N	+	+	−	−	+
O	+	+	+	−	−
P	+	−	−	+	−

	1	2	3	4	5
Q	−	−	−	+	−
R	+	−	+	−	+
S	−	+	−	+	+
T	+	+	+	+	−
U	−	−	−	+	+
V	+	−	−	−	−
W	−	−	+	+	−
X	−	+	−	−	−
Y	−	+	−	+	−
Z	−	+	+	+	−
Space	+	+	−	+	+
Car. Ret.	+	+	+	−	+
Line Feed	+	−	+	+	+
Figures	−	−	+	−	−
Letters	−	−	−	−	−

Five-unit code.



Specimen of tape with all characters perforated.

Fig. 1—Combinations of Positive and Negative Impulses Representing the Different Characters

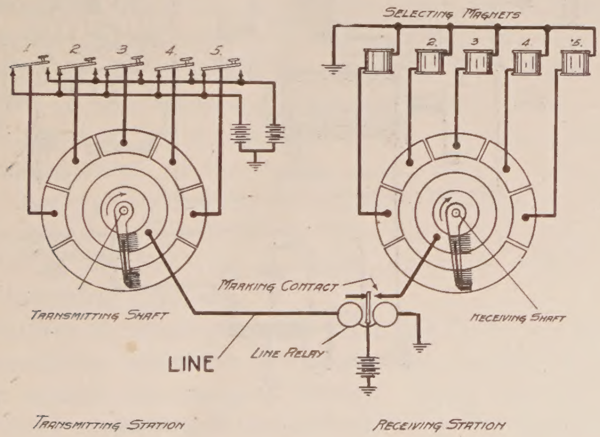


Fig. 2—Schematic Wiring Diagram of Transmitting and Receiving Apparatus

A five-unit code provides 32 combinations of positive and negative impulses as in the multiplex system. These impulses are used to operate five selecting magnets in the printer. For every character selected, one or more of the selecting magnets is operated. This makes it possible to select any one of the 26 letters of the alphabet or any one of the functions such as "space," "carriage return," "line feed," "figure shift," or "letter shift." Counting both the upper and the lower case positions, 52 letters, numbers or other characters are possible. Fig. 1 shows the various combinations of positive and negative impulses that represent each of the different characters.

Motor-driven distributors are employed at both the sending and the receiving stations to transmit the line signals from the sending station at a uniform rate of speed and to receive and interpret these signals at the receiving station. The speed of the motors at each end of the line is maintained uniform by governors.

Fig. 2 is a schematic wiring diagram showing the principle involved in sending and receiving.

The speed at which signals are sent over the line depends on the speed of the transmitting shaft at the sending end. As the line relay at the receiving end operates in accordance with these signals, in order to select any one of the five selecting magnets in the printer, the receiving brush arm must pass over the corresponding receiving segment at the same time that a marking impulse is sent over the line and the line relay tongue is resting against its marking contact.

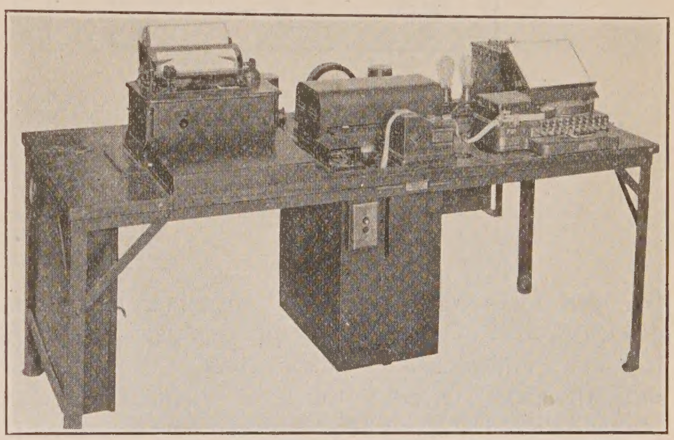


Fig. 3—Morkrum Terminal Set

When the transmitting station stops sending, the receiving brush arm is held stationary by a magnet. At the beginning of each set of signals, a start impulse precedes the first selecting impulse and operates this magnet thereby releasing the receiving brush arm. The five selecting impulses follow and the proper selecting magnets are operated successively as the brushes pass over the receiving segments.

These fundamental features apply to all three systems but the method by which line signals are transmitted from the sending station and interpreted at the receiving end is quite different in each system.

Morkrum "Green Code" System

Fig. 3 shows a Morkrum terminal set. The perforator is shown at the right and the printer at the left with the transmitter and distributor between them.

2. John H. Bell "Printing Telegraph Systems," loc. cit.

Transmission. Fig. 4 is a schematic wiring diagram of the circuits involved in transmitting signals over the line.

The tape that is prepared by the perforator is fed through the transmitter and is stepped forward once for each revolution of the transmitting brush arm, Fig. 4, in the distributor. Fig. 5 shows the tape-feeding mechanism. When the contact *A B*, in the distributor, is closed, the transmitter magnet moves lever *A C* clockwise about its pivot *A D* and feeds

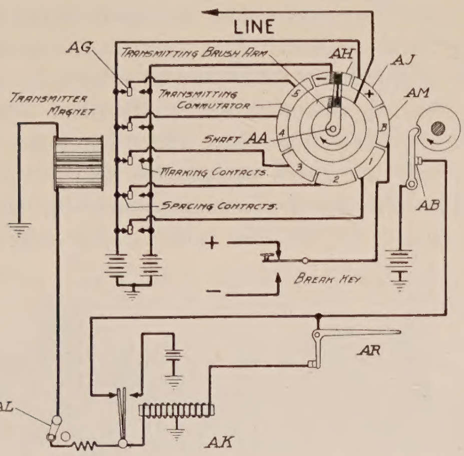


Fig. 4—Schematic Wiring Diagram of Transmitting Circuits

the tape forward. When the transmitter magnet is de-energized it allows the tape pin contact levers *A E* to move counter-clockwise about their pivot point *A D* until the pins *A F* reach the level of the tape. If a pin is blocked by the tape the contact tongue *A G* remains against its spacing contact. If the perforations in the tape permit a pin to go through the tape, however, the corresponding contact tongue *A G* moves over against its marking contact. There are five pins *A F* and five contact tongues *A G* and each contact tongue is connected to a segment on the transmitting commutator. Consequently when the transmitter magnet is de-energized each segment will be connected to marking or spacing battery according to the perforations in the tape. Segment *A H* is permanently connected to marking battery and segment *A J* is permanently connected to spacing battery. As the transmitting shaft *A A* revolves, the brush first sends a spacing signal which is called the start impulse and then the selecting impulses in accordance with the code combination set up in the transmitter.

The speed may be set so that transmission is carried on at any desired rate from 40 to 65 words per minute.

For every revolution of the transmitting shaft, eight impulses are sent to the receiving station. Two are for synchronizing purposes, one is for sending a bell signal to the distant station without interfering with the message being transmitted, and five are for selecting purposes. Communication is therefore carried on at a line frequency of eight units or 4 cycles per character. Sixty words per minute represents a line frequency of 24 cycles per second.

The transmitting shaft is not stopped after each revolution but continues to revolve until transmission is stopped by the raising of the arm *A R*. Normally when the transmitter cam contacts *A B* are closed, current flows through both windings of the differentially wound auto-stop relay *A K*. The transmitter magnet is therefore operated but as the current flows through the auto-stop relay windings in opposite directions, the latter will not be operated. If, however, the auto-stop arm *A R* is lifted and the transmitter cam contacts closed, current will flow through the transmitter magnet and through only one winding of the relay. This operates both the transmitter magnet and the relay— the relay locking itself in the operated position. The transmitter magnet remains energized until the auto-stop arm is again lowered. During this time the pins are held down and transmission of code combinations is stopped, but the transmitting brushes continue to revolve, sending out starting impulses once every revolution.

If for any reason, it is desired to repeat a character a number of times the switch *A L* may be opened, thereby opening the circuit to the transmitter magnet and allowing the tape to remain stationary with the proper marking and spacing battery combination set up at contact tongues *A G*. Inasmuch as the tape is not stepped forward, the same character is sent over

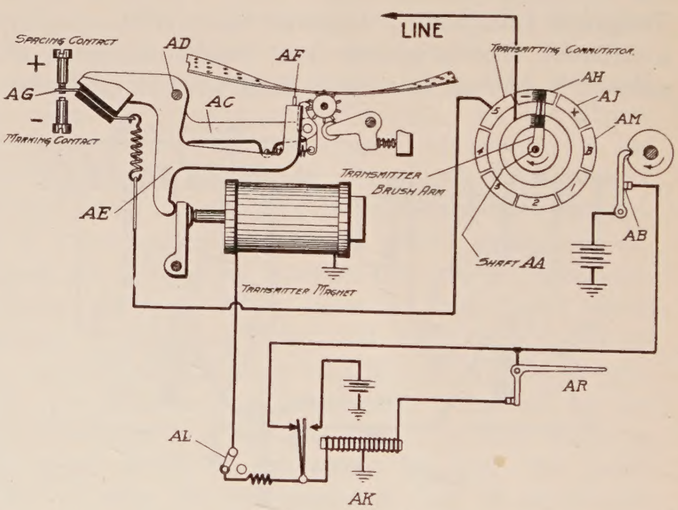


Fig. 5—Tape-Feeding Mechanism

and over again as long as the switch *A L* remains open and the brush arm continues to revolve.

In order to signal quickly to the distant station an extra segment *A M* (Fig. 4) is provided on the transmitting commutator. When the break key is held down, marking battery is connected to the segment *A M* and a marking impulse is sent over the line immediately after the start impulse. This impulse operates a bell at the receiving station in a manner which will be described later.

Reception. Fig. 6 shows the manner in which the receiving units are connected electrically.

The brush arm $A\ N$ is mounted on a sleeve together with the start magnet cam $A\ S$ the break circuit cam $A\ P$ and the stop cam $A\ T$. A motor drives this sleeve through a clutch, at a speed slightly higher than the speed of the transmitting shaft at the sending end. This increased speed is compensated for by delaying the brush arm after each character sufficiently to keep the sending and receiving stations in step.

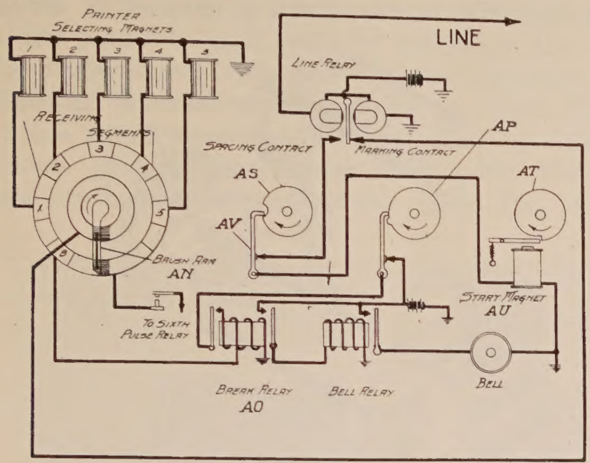


Fig. 6—Electrical Connections of Receiving Units

Normally the brush arm is held stationary by the start magnet $A\ U$ with the start magnet contact $A\ V$ closed. When transmission is started a spacing impulse precedes the bell and selecting impulses, a circuit is completed through the spacing contact of the line relay, the start magnet is operated, and the brush arm is released. After the brush arm is released it revolves at a rate of speed slightly higher than that of the transmitting brush arm but the distance from center to center of the receiving segments is such that the time required for the brushes to pass from the center of one segment to the center of the next is equal to the time required for the transmission of one impulse of unit length. The brushes therefore, pass over the center of the receiving segments durng the middle of the incoming impulses.

Battery is connected to the solid ring of the receiving commutator whenever the line relay tongue moves over against its marking contact. Each one of the receiving segments is connected to a corresponding selecting magnet in the printer. If, therefore, the brush passes over receiving segment No. 1 while the line relay tongue is against its marking contact the first selecting magnet will be energized, and similarly with the second, third, fourth and fifth selecting magnets. As the brushes pass over each segment in turn they will or will not carry current to each successive selecting magnet according to whether or not the line impulse then being received is of marking or spacing polarity.

If a marking impulse is received directly after the start impulse the line relay tongue will be resting against its marking contact as the brushes pass over the bell segment B and the break relay $A\ O$ will be operated. This relay in turn operates a bell through the bell relay. Attached to the brush arm sleeve is a break cam $A\ P$ which breaks the locking circuit to the quick-acting break relay $A\ O$ just before the receiving brushes reach the segment B. If the receiving brushes reach this segment before the break key at the transmitting station is released, the break relay will again be operated before the slow acting bell relay has time to open the circuit to the bell. Only one bell signal is transmitted no matter how long the break key is held down.

After the brushes pass over the bell segment and the five selecting segments they complete a circuit through the marking contact of the line relay to the sixth pulse relay in the printer.

The printer, Fig. 7, used with this system, prints from a typewheel, which rotates to the proper letter and is then thrown forward against the paper. After each letter is printed the typewheel itself is stepped to the right, the paper remaining stationary, and at the end of each line of printing the paper is moved upward.

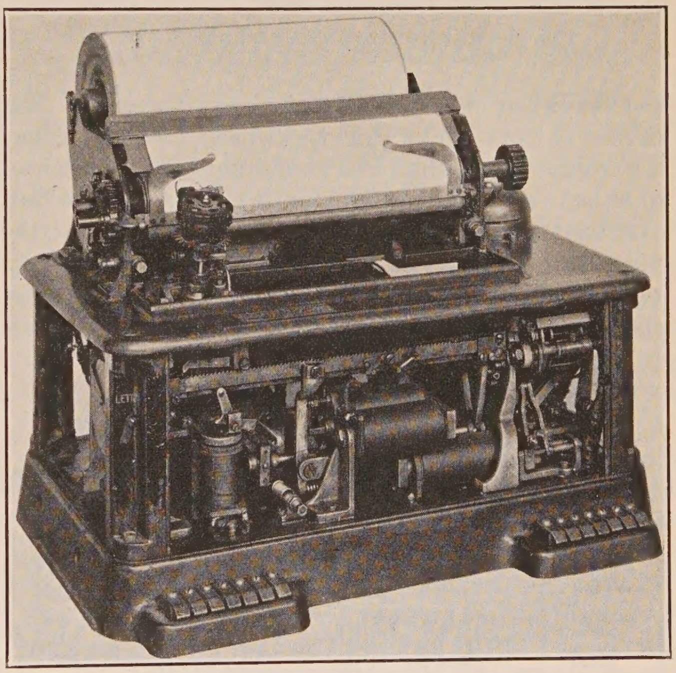


Fig. 7—Printer Used with Morkrum "Green Code" System

When a selecting magnet is energized, a disk or interference plate is rotated as shown in Fig. 8. There are four interference plates controlled by the first, second, third and fifth selecting magnets. The fourth selecting magnet does not move an interference plate but operates the fourth-pulse relay which in turn decides the direction of rotation of the typewheel.

The arrangement of the five-unit code (Fig. 1) is such that there are exactly 16 combinations which contain the fourth pulse and 16 combinations which do not contain the fourth pulse. The printer is arranged, therefore, so that whenever a code combination containing the fourth pulse is received, the typewheel revolves counter-clockwise and when a code combination that does not contain the fourth pulse is received

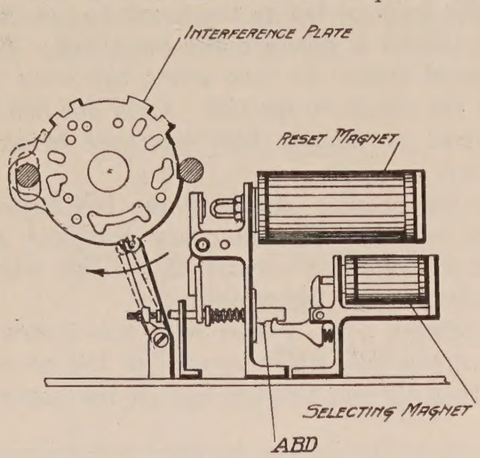


Fig. 8—Rotation of Interference Plate

the typewheel revolves in a clockwise direction. The degree of rotation of the typewheel, for any letter, is a fraction of one-half of a revolution of the typewheel in either direction depending on the character selected.

After the interference plates are moved, the sixth-pulse relay (Fig. 9) is operated and supplies battery to the drum magnet. When the drum magnet is energized it pushes a set of stop pins against the inter-

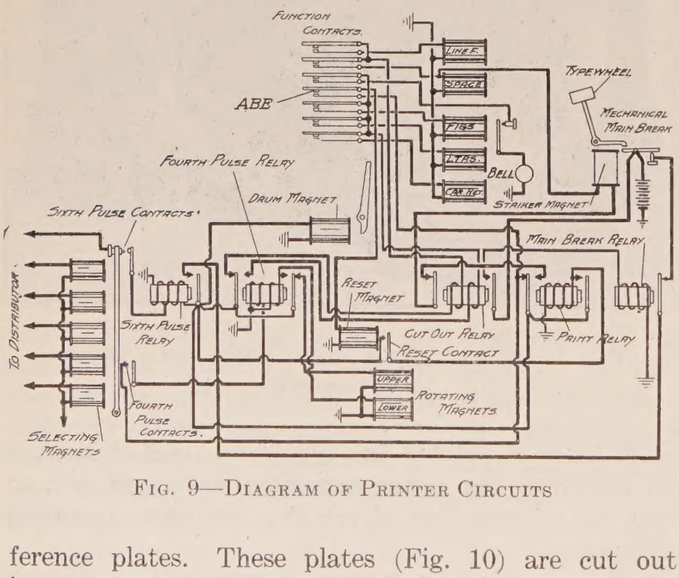


Fig. 9—Diagram of Printer Circuits

ference plates. These plates (Fig. 10) are cut out in such a way that only two pins are allowed to go through all four plates at any one time.

If the letter "E" for instance is selected, the first interference plate is moved and the operation of the drum magnet pushes two pins through the interference plates. These pins $A\ Y$ and $A\ Z$, are on opposite sides of an index arm $A\ W$ which is connected to the typewheel by means of the square shaft $A\ X$. Inasmuch as the "E" code combination does not contain the fourth pulse, the fourth-pulse relay will not be operated and the operation of the sixth-pulse relay will connect battery to the *upper* set of rotating magnets thereby rotating the typewheel clockwise until the index arm $A\ W$ strikes the pin $A\ Y$. If, however, the letter "D" is selected, not only the first selecting magnet but also the fourth selecting magnet is energized

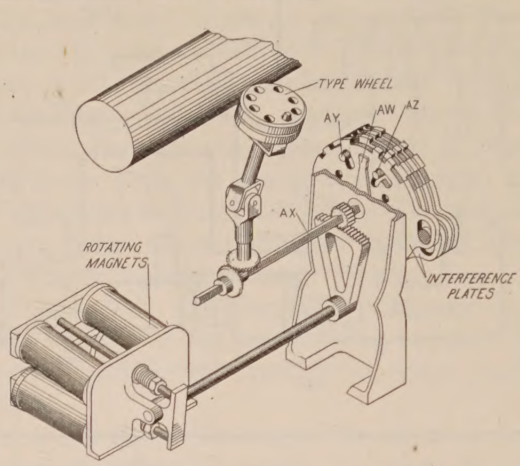


Fig. 10—Operation of Interference Plates

thereby operating not only the first interference plate but also the fourth-pulse relay. In this case the same pins are pushed through the interference plates as for the letter "E" but in the case of the letter "D" selection, the operation of the fourth-pulse relay directs battery to the *lower* set of rotating magnets, when the sixth-pulse relay is operated. The typewheel is then rotated counter-clockwise until the index arm strikes the pin $A\ Z$.

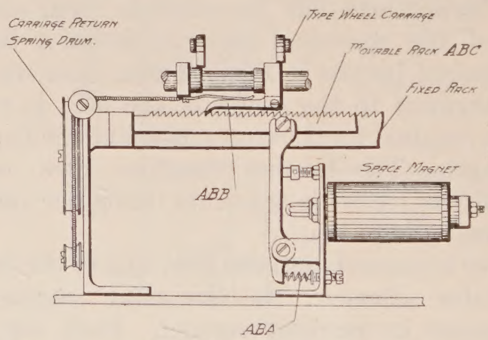


Fig. 11—Operation of Space Magnet

When the pins are pushed through the plates a contact $A\ B\ E$ (Fig. 9) is closed and the reset magnet (Fig. 8) is operated. The operation of the reset magnet restores the trip rods $A\ B\ D$ and closes the reset contact (Fig. 9). When the reset contact is closed a circuit is completed through the print relay contacts and the striker and space magnets are energized. The operation of the space magnet (Fig. 11) compresses a spring $A\ B\ A$ which in turn spaces the typewheel carriage forward when the space magnet is released. The

striker magnet throws the typewheel against the platen thereby printing the selected character and opening the mechanical main break contact. The opening of the main break contact (Fig. 9) breaks the locking circuit to the sixth-pulse relay, and as the current to all of the magnets is routed through the sixth-pulse relay contact, battery is disconnected from the drum magnets, the rotating magnets, the striker magnet and the space magnet. The typewheel is spaced one space forward and the printer is again ready to gothrough the same cycle of operationsf or the next selected character.

Spacing between words, shifting to print figures, and the other functions, are controlled by function contacts (Fig. 9) located over notches cut in the top edges of the interference plates. When the "space"

FIG. 12—WESTERN ELECTRIC TERMINAL SET

signal is received, for instance, the third interference plate is moved and a notch, under the space contact, allows the latter to close thereby connecting battery to the space magnet through one winding of the cut-out relay. When the space magnet is energized, the cut-out relay is also operated, closing a circuit to the main break relay. This relay opens the locking circuit of the sixth-pulse relay and disconnects battery from the space magnet. During this operation the reset magnet and the print relay are operated as usual but no printing occurs inasmuch as the circuit to the striker magnet is broken through the back contact of the cut-out relay.

On the under side of the typewheel carriage are mounted two pawls *A B B* (Fig. 11) which mesh with a fixed rack and a movable rack *A B C* located directly under them. When the spacing magnet is energized, the movable rack is moved to the left so that one of the pawls drops into the next tooth on the rack. When the spacing magnet is de-energized, the movable rack is returned to its normal position by the spacing spring *A B A* and moves the carriage forward one space.

When a "carriage return" selection is received, the carriage return function contact operates the cut-out relay and a carriage return solenoid. This solenoid raises a bar located between the two racks, lifting the pawls clear of the teeth. The typewheel carriage is then drawn to the left for a new line of printing by a cord wound around a spring-operated drum.

When the "figure shift" signal is received, the figures magnet is energized through the figures function contact and one of the windings of the cut-out relay. The figures magnet moves the typewheel upward, ready for the printing of numbers or punctuation marks.

When the "letter shift" signal is received the letters function contact is closed, thereby operating the letters magnet which releases the catch that holds the type-wheel in its upper case position.

When the "line feed" signal is received, a line feed magnet is operated by the line feed function contact and, by means of a pawl and ratchet mechanism, feeds the paper upward ready for a new line of printing.

WESTERN ELECTRIC "START STOP" SYSTEM

Fig. 12 shows a Western Electric terminal set. The perforator is shown at the right with the printer directly behind it and the transmitter is shown at the left in front of the distributor.

Transmission. Fig. 13 is a schematic wiring diagram of the circuits involved in transmitting signals over the line.

The Western Electric system is equipped for either direct keyboard or perforated tape operation and may be operated at any desired speed from 40 to 65 words per minute.

The tape that is prepared when the perforator is used is fed through the transmitter and is stepped forward once for every revolution of the transmitting brush arm *B B* in the distributor. Fig. 14 shows the tape feed mechanism. When the brushes pass over the transmitter segment *B C* (Fig. 13) the transmitter magnet (Fig. 14) moves lever *B D* about its pivot *B E* and feeds the tape forward.

When the transmitter magnet is de-energized, the tape pins *B F* move upward until the tops of the pins reach the level of the tape. If a pin is blocked by the tape the contact tongue *B G* remains against its spacing contact. If the perforations in the tape permit a pin to go through the tape, the corresponding contact tongue *B G* will move over against its marking contact. There are five pins *B F* and five contact tongues *B G* and each contact tongue is connected to a sending relay (Fig. 13). Consequently when the transmitter magnet is de-energized and battery is applied to the marking contacts, the proper sending relays will be energized according to the perforations in the tape. Whenever a sending relay is energized, it closes a

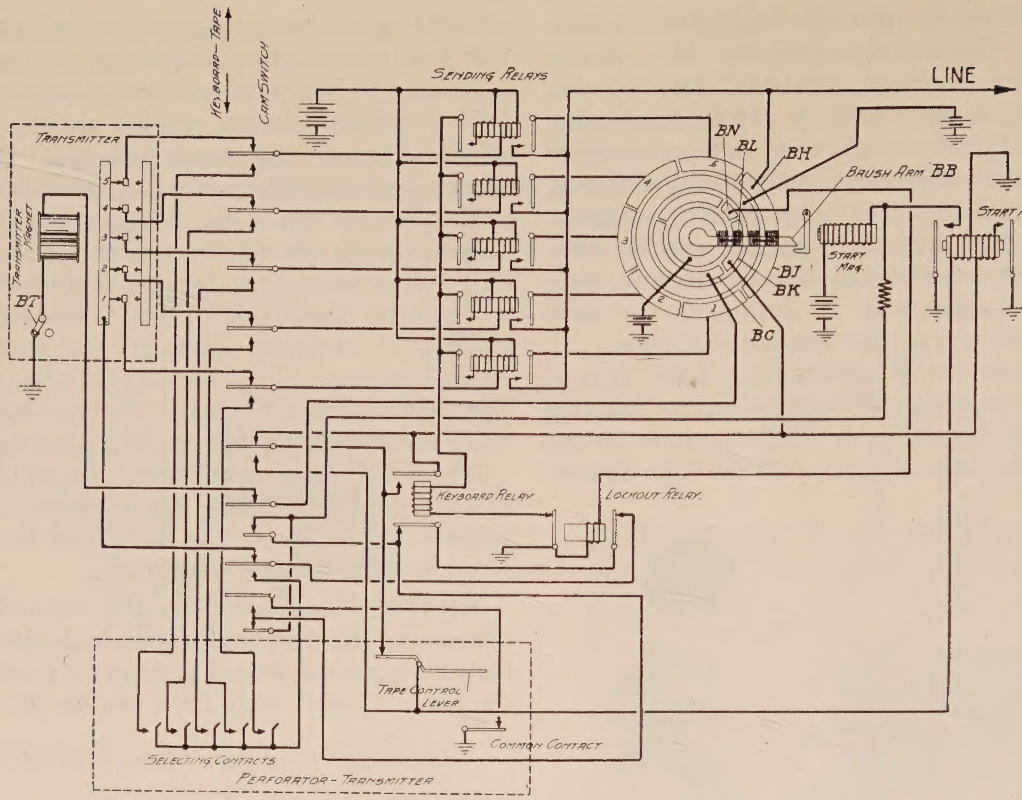


FIG. 13—SCHEMATIC WIRING DIAGRAM OF TRANSMITTING CIRCUITS

circuit to the corresponding transmitting segment and a locking circuit holds the relay operated.

To send a marking impulse, the line is closed, and to send a spacing impulse the line is opened. Segments $B\,H$ and $B\,J$ are wired so that when the brushes pass over segment $B\,H$ the line will be closed and when they pass over segment $B\,J$ the line will be opened. As the transmitting brushes revolve they first send out a spacing signal which is called the start impulse and then the selecting impulses in accordance with the code combination set up in the sending relays.

In order to send positive and negative impulses to the receiving station, a pole-changer may be operated from the transmitting segments. The signals are then sent over the line from the pole-changer.

For every revolution of the transmitting brushes, seven impulses are sent to the receiving station. Two are for synchronizing purposes and five are for selecting purposes but one of the synchronizing impulses is longer than the other. Communication is therefore carried on at a line frequency of between seven and eight units or between three and one-half and four cycles per character. Sixty words per minute represents a line frequency of a little over 21 cycles per second.

The transmitting brush arm $B\,B$ is stopped once every revolution but is almost immediately released provided the tape control lever contact is closed. If, however, the tape control lever contact is open when the local brushes $B\,L$ reach the segment $B\,K$, the circuit to the start relay will be open and the start magnet will not be operated. The brush arm will then come to rest so that the transmitting brushes rest on the segment $B\,H$ thereby closing the line until transmission is again started.

When the tape control lever contact is again closed it completes a circuit through the local segment $B\,K$

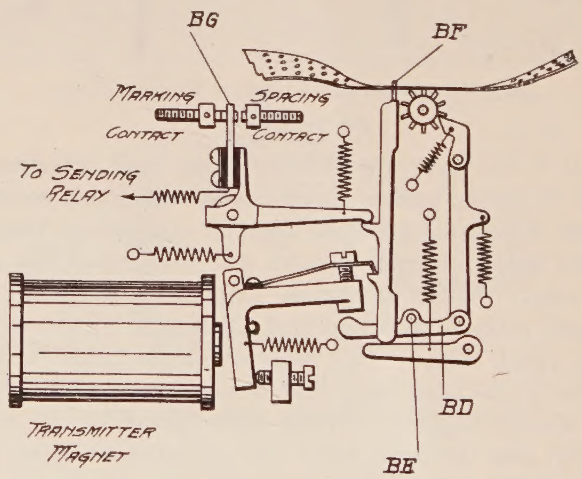


FIG. 14—TAPE-FEED MECHANISM

to the start relay and starts transmission. The start relay in turn operates the start magnet, the transmitting brush arm is released and circuits to the sending relays are closed through the marking contacts in the transmitter.

When the local brushes leave the segment $B\,K$, the locking circuit to the start relay is broken, the start

relay is de-energized and the circuit to the marking contacts in the transmitter is broken. During the time that the start relay is energized the selection is transferred from the transmitter to the sending relays ready to be sent to the receiving station one impulse after the other as the transmitting brushes pass over segments Nos. 1, 2, 3, 4 and 5.

Directly after the circuit to the marking contacts in the transmitter is broken the local brushes pass over segment *B C* operating the transmitter magnet and stepping the tape forward so that the next character in the perforated tape is presented above the pins.

If it is desired to repeat a character a number of times the switch *B T* may be operated to open the circuit to the transmitter magnet. Inasmuch as the tape is not stepped forward, the same character is sent over and over again as long as the switch *B T* remains open and the brush arm continues to revolve.

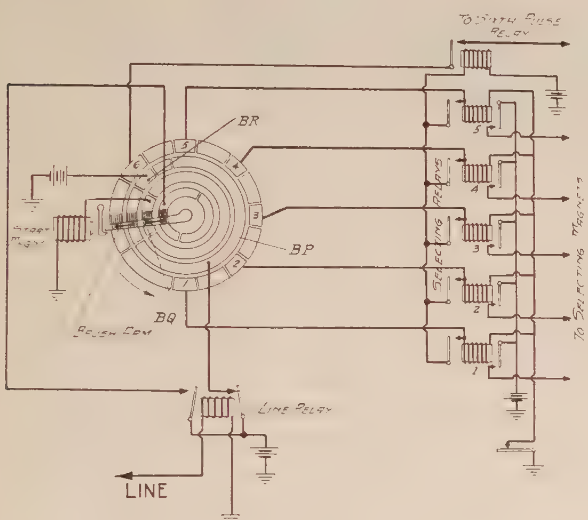


Fig. 15—Electrical Connections of Receiving Units

After the fifth selecting impulse is sent, the local brushes pass over segment *B N* and the lockout relay is energized. The operation of this relay breaks the locking circuit to the sending relays and the relays are de-energized.

As long as the tape control lever contact remains closed, the start relay and start magnet will be energized whenever the local brushes pass over the segment *B K* and the transmitting brush arm will therefore continue to revolve.

With direct keyboard operation the circuit to the transmitter magnet remains open and the selection that is set up on the selecting contacts in the perforator-transmitter, whenever a key lever is depressed, is transferred directly to the sending relays. From that point the operation of transmitting a character is practically the same as that described above.

In order to prevent sending a second selection to the sending relays before the first selection is sent over the line the common return wire from the keyboard selecting contacts is routed through the back contact of the keyboard relay which is in series with the locking circuit for the sending relays. When the sending relays are de-energized, by the operation of the lock-out relay, the back contact of the keyboard relay is again closed permitting the next selection to be sent from the selecting contacts to the sending relays.

With keyboard operation a contact that is closed by the operation of the keyboard relay takes the place of the tape control lever contact described above. The transmitting brush arm stops, therefore, after every revolution and remains stationary until a key lever is depressed and the keyboard relay is operated.

Reception. Fig. 15 shows the manner in which the receiving units are connected electrically.

The light brush arm is clutch-driven and the speed of the shaft that drives the brush arm is the same as the speed of the transmitting brush arm at the sending end. When the start impulse is received the receiving brush arm is released and revolves at the same speed as the transmitting brush arm.

Normally the brush arm is held stationary by the start magnet with the local brushes resting on the start segment *B Q*. When the receiving brushes are at rest and the line is opened battery is supplied to the start magnet through the back contact of the line relay and the brush arm is released.

When the line is closed battery is connected to the segment *B P* through contacts on the line relay, and when the line is opened battery is cut off. If the line is closed, therefore, when the receiving brushes pass over segment No. 1, the first selecting relay will be energized and similarly the second, third, fourth and fifth selecting relays. As the brushes pass over each segment in turn they will or will not carry current to each successive selecting relay according to whether the line is closed or open at that particular instant.

After the brushes pass over the five selecting segments a local circuit is completed through segment *B R* and segment No. 6 to the sixth-pulse relay in the printer and the brush arm is again stopped by the start magnet armature.

The printer, Fig. 16, is of the movable-carriage type where the paper that receives the message is moved one space to the left after each character is printed. Printing is accomplished by pushing the paper against a type wheel which revolves in one direction on a vertical shaft and which may be raised or lowered for printing upper or lower case characters. This printer is described in J. H. Bell's Institute paper on printing telegraph systems and therefore needs no further mention.

Kleinschmidt System

Fig. 17 shows a Kleinschmidt terminal set. The perforator is shown at the right and the printer at the left with the transmitting and receiving distributors between them.

Transmission. Fig. 18 is a wiring diagram of the circuits involved in transmitting signals over the line. The transmitting mechanism is entirely mechanical and is like that of a Wheatstone transmitter.

The tape that is prepared by the perforator is fed through the transmitting distributor and is stepped forward by means of the cam *H* and the pawl *J*, once for every half revolution of the transmitting shaft *A* (Fig. 19). For every revolution of the transmitting shaft two characters are sent over the line.

The transmitting cam shaft *A* is motor-driven through a friction clutch at any desired speed from 40 to 80 words per minute. As the shaft *A* revolves, the cam *B* moves lever *C* about a pivot *D* allowing the spring *E* to draw the pin *F* upward. If a hole in the perforated tape presents itself above the pin *F*, the latter pin will pass through the tape and the contact

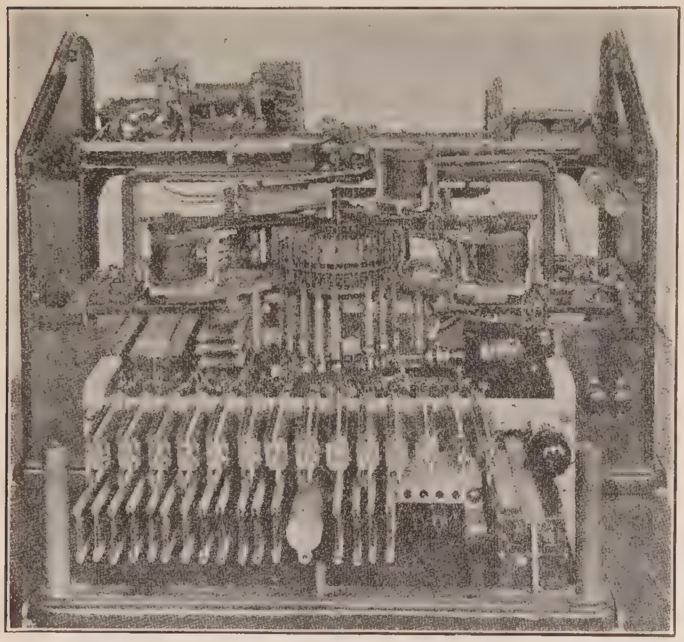


Fig. 16—Western Electric Printer

tongue *G* will move over against its negative or marking contact as shown. If, however, the pin *F* is blocked by the tape, the contact tongue *G* will remain against its positive or spacing contact as illustrated in Fig. 20. Six cams *B*, six levers *C* and five pins *F* are located one behind the other and operate in succession.

The contact tongue is connected directly to the line. Positive and negative impulses are therefore sent over the line as the five pins *F* move upward, one after the other, and are blocked or are not blocked in accordance with the perforations in the tape.

At the beginning of every character one of the cams on the transmitting shaft *A* actuates a train of mechanism similar in every respect to that described above, except that no vertical pin *F* is included. At the beginning of each character the transmitting tongue moves to the right and sends out a marking impulse. This impulse is followed by the five selecting impulses and then a spacing impulse.

For every character transmitted, therefore, seven impulses are sent to the receiving station. Two are for synchronizing purposes and five are for selecting purposes. Communication is carried on at a line frequency of seven units or three and one-half cycles per character. Sixty words per minute represents a line frequency of 21 cycles per second.

Fig. 17—Kleinschmidt Terminal Set

The transmitting cam shaft *A* is not stopped after each character, but revolves constantly, sending out one character after another until the sending station wishes to stop transmission, which may be done at any time by moving a lever in the path of a stop arm attached to the transmitting cam shaft *A*. When the cam shaft *A* is stopped transmission ceases although the motor continues to drive the friction clutch through which the cam shaft is driven.

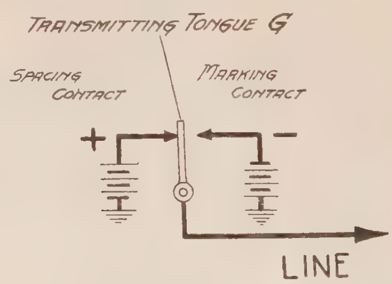


Fig. 18—Diagram of Marking and Spacing Contracts

If, for any reason, it is desired to repeat a character a number of times, the button *O* (Fig. 20) may be depressed so as to hold the pawl *J* out of engagement with the tape feed wheel ratchet. In this way the tape will remain stationary and the same character will be sent over and over again as long as the transmitting cam shaft *A* continues to revolve and the button is depressed.

In order to signal quickly to the distant station, a bell signal mechanism is provided as illustrated in

Fig. 21. Shaft K is clutch-driven and revolves only when the bell handle L is moved to the right. When the handle L is moved to the right, and then released, the shaft K is released and the transmitting cam shaft A is stopped during one revolution of the shaft K. During this revolution the cam M moves the contact tongue G back and forth by means of the levers shown, sending the characters "figure shift," "J," and "letter shift" over the line. Whenever the letter "J" is selected

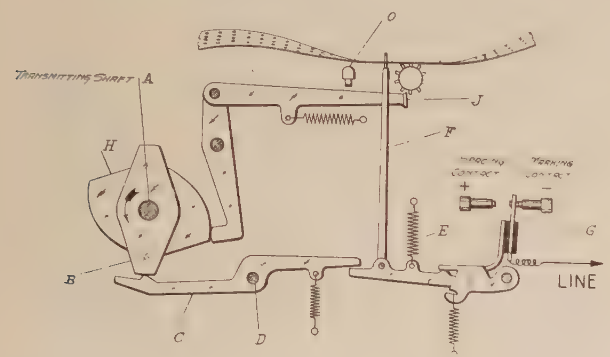


Fig. 19—Tape-Feeding Mechanism—Marking Contact

in the printer, while the carriage is in the upper case, a bell is rung and no printing takes place. If the bell handle L is held over to the right when the shaft K completes one revolution the latter will continue to revolve sending out a bell signal to the distant station once every revolution as long as the bell handle is held over. When the bell handle is released, however, the shaft K will be stopped and the transmitting cam shaft A will continue its motion. At the beginning of each revolution of the shaft K, a small mechanical

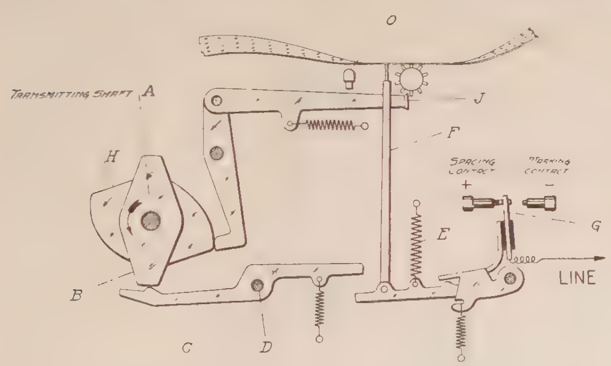


Fig. 20—Tape-Feeding Mechanism—Spacing Contact

bell is operated so that the operator at the sending station may know how long to hold the bell handle L to the right in order to send out any desired number of bell signals.

Reception. Fig. 22 shows the manner in which the receiving units are connected electrically.

The receiving distributor is entirely separate from the transmitting distributor. This necessitates two motors, but with this arrangement transmission may be carried on in opposite directions at different speeds and accurate speed adjustments are not necessary. The light brush arm N is clutch-driven at a speed slightly faster than the speed of the transmitting cam shaft at the sending end. This increased speed at the receiving station is compensated for by delaying the brush arm, after each character is received, sufficiently to keep the sending and receiving stations in step.

Normally the brush arm is held stationary by the

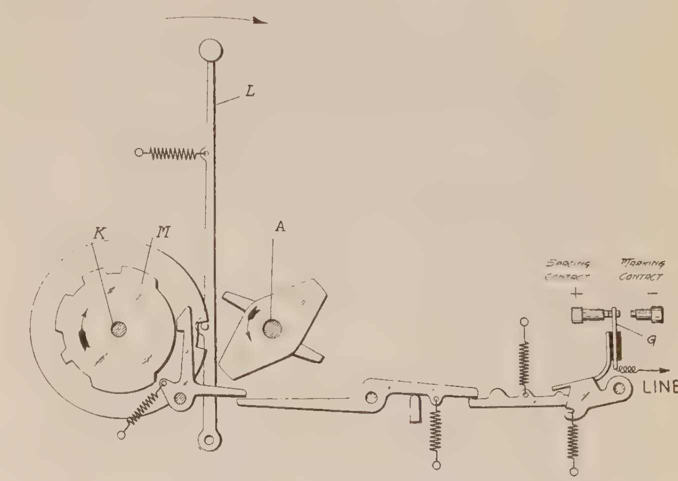


Fig. 21—Bell Signal Mechanism

start magnet armature with the brush resting on the start segment and the relay tongue held against its spacing contact. When a character is received a marking impulse precedes the first five selecting impulses and a circuit is completed through the marking contact of the line relay, the start magnet then is operated and the brush arm released.

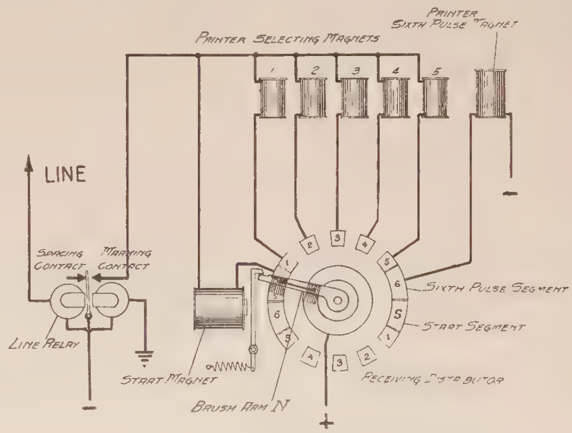


Fig. 22—Electrical Connections of Receiving Units

Positive battery is connected to the solid ring of the receiving distributor and the marking contact of the line relay is in series with the common return wire for the selecting magnets and the start magnet. Each one of the selecting magnets in the printer is connected to a corresponding receiving segment. If, therefore, the brush passes over receiving segment No. 1 while the line relay tongue is against its marking contact, the first selecting magnet will be energized and similarly the second, third, fourth and fifth selecting magnets. As

the brushes pass over each segment in turn they will or will not carry current to each successive selecting magnet according to whether or not the line impulse then being received is of marking or spacing polarity.

After the brushes pass over the five selecting segments they pass over a sixth-pulse segment, completing

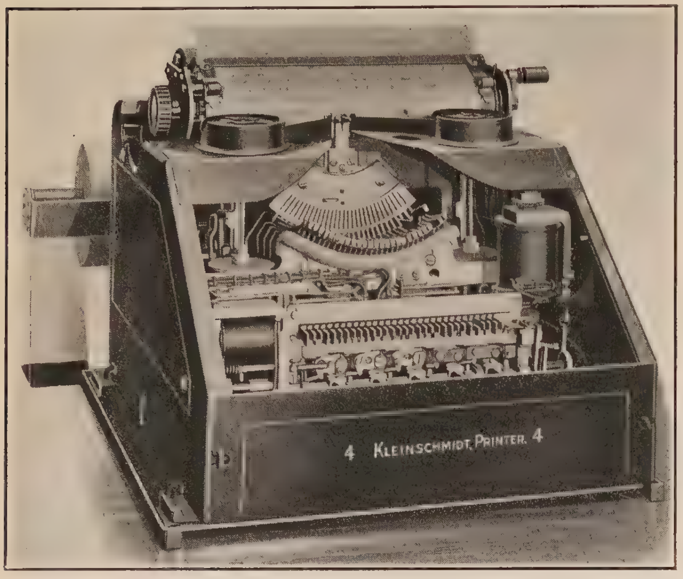


FIG. 23—KLEINSCHMIDT PRINTER

a circuit through the sixth-pulse magnet in the printer and then again come to rest on a start segment.

The printer, Fig. 23, is a type-bar printer of the movable-paper carriage type similar to a standard typewriter. The paper is moved to the left after each character is printed and is fed upward at the end of each line of printing.

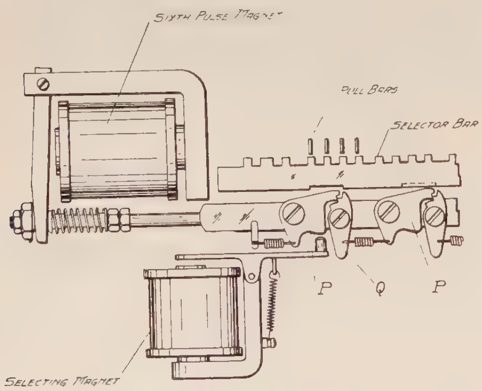


FIG. 24—OPERATION OF SELECTING MAGNET

When a selecting magnet is energized its armature lifts a pawl P (Fig. 24) in the path of a selector bar and a latch Q locks it in this position. Five pawls P are located on a bar that is moved by the sixth-pulse magnet. When the selection is stored up in the pawls on this bar, the sixth-pulse magnet is operated and the pawls that were lifted move the corresponding selector bars to the right.

Each type-bar (Fig. 25) is connected to a pull-bar mounted directly above and at right angles to the selector bars. When one or more of the selector bars is moved to the right a slot is presented under one of these pull-bars and the selected pull-bar drops so that a hook on the under side of the pull-bar is in the path of an operating bail R. This bail is moved by an operating solenoid whenever a pull-bar drops into a

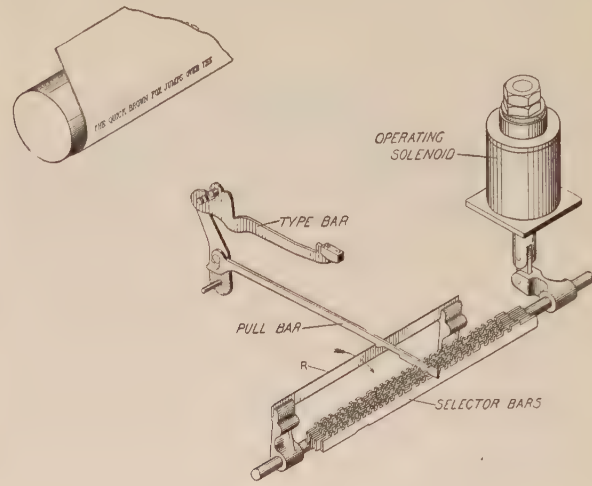


FIG. 25—OPERATION OF TYPE BAR

slot in the selector bars. In this way the selected type-bar is thrown upward and the proper character is printed.

Spacing after every letter is provided for by means of a spacing solenoid which is energized whenever a type-bar moves upward. Spacing between words is accomplished in a similar manner except that the type-

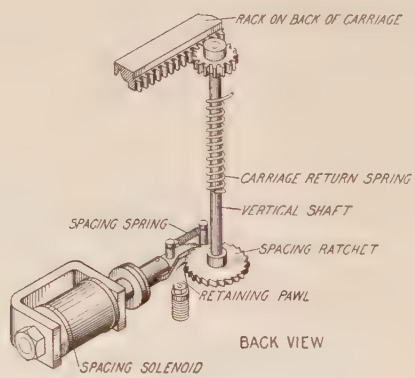


FIG. 26—OPERATION OF CARRIAGE

bar selected does not carry any type and therefore does not print.

On the back of the carriage a rack (Fig. 26) is mounted which meshes with a gear on top of a vertical shaft. The spacing solenoid turns the ratchet on the bottom of this vertical shaft, the motion being transmitted to the carriage by means of the vertical shaft, and the carriage is thus stepped forward after each character is printed. The spacing ratchet is not

rigidly attached to the vertical shaft, however, but drives it through a clutch (not shown). A carriage return spring is wound up as the carriage is spaced along and exerts a force on the vertical shaft tending always to return the carriage to the beginning of a new line of printing. When the clutch is in its normal closed position this force is held in check by a retaining pawl acting against the spacing ratchet. When the "carriage return" signal is received, the "carriage return" pull-bar drops into its notch in the selector bars and a contact is closed, thereby operating a carriage return magnet which disengages the clutch. The spring on the vertical shaft is released from the restraining action of the retaining pawl and returns the carriage to the beginning of a new line of printing. When the carriage reaches this position it opens the locking circuit to the carriage return magnet and the clutch is returned to its normal closed position, again connecting the spacing ratchet to the vertical shaft.

The various other functions are either performed mechanically directly from the pull-bars or are operated by means of solenoids controlled by the pull-bars.

When the "figure shift" signal is received, for instance, the "figure shift" pull-bar drops into its notch in the selector bars and a contact is closed thereby energizing the shift solenoid. The latter then lifts the front end of the carriage and a latch holds it in its shifted position so that figures or punctuation marks may be recorded. When a "letter shift" signal is received and the "letter shift" pull-bar is moved forward by the operating bail the latch is released mechanically and the carriage drops back to its normal position.

A ratchet that is operated by a pawl is mounted on the platen around which the paper is fed. This pawl is attached to a bail extending the length of the carriage and is operated by the line feed solenoid. When a "line feed" signal is received, the operation of the proper pull-bar energizes the line feed solenoid and the paper is therefore moved upward a distance of one line space to the next line of printing.

NOTES FROM THE BUREAU OF STANDARDS

STANDARDIZATION OF DRY CELLS

An important meeting was held at the Bureau of Standards in December at which the standardization of sizes and specifications for dry cells was considered. Manufacturers of about 95 per cent of the flashlight batteries and dry cells, as well as many of the Government departments and other users, were represented at the meeting.

This conference has grown out of some important work carried out by the Bureau in 1918. When the war was in progress, it was important to eliminate so far as possible unnecessary sizes of articles and also to buy them according to specifications. This was particularly true in the case of batteries of which large numbers were required by the army and navy.

In cooperation with the War Industries Board, the Bureau of Standards prepared a list of standard sizes and specifications governing many types of dry cells. After the war when the restrictions imposed by the War Industries Board were removed, many of the manufacturers felt it necessary again to take up the production of a large number of sizes of cells many of which are not in very general use.

The conference considered 17 sizes of dry cells and standardized 7 of these sizes. It considered 30 different sizes and kinds of flashlight batteries and adopted 8 of these as standard sizes. Two sizes for use with radio apparatus were standardized. It is expected that the elimination of many sizes for which there is little demand and which will no longer be considered as standard will result in considerable saving in the cost of manufacture and increase the convenience of the public who buy these batteries to the extent of approximately 150,000,000 per year. In addition to the standardization of sizes, the conference standardized the performance for the sizes which were accepted.

The Bureau was requested to make a revision of its specifications for dry cells in conformity with the standards as adopted by the conference.

REVISION OF SPECIFICATIONS FOR INCANDESCENT LAMPS

Recently conferences were held with representatives of the General Supply Committee and several lamp companies in connection with the revision of specifications and proposals for supplying lamps under government contract for the next fiscal year. In general, a consistent effort is being made to eliminate from the schedules all special lamps.

The lamps formerly classified under the 110- and 125-volt range have all been grouped in four voltages, namely 110, 115, 120, and 125, and similarly lamps of 220-volt range have been grouped into 10-volt steps. This is in conformity with the best commercial practise, and some pressure has been brought to bear upon other departments to change circuits which are now operated at other voltages, so as to use even 5- or 10-volt steps. The 20- and 60-volt groups which have been carried for a number of years, will be cut out next year. A number of older sizes, such as the 100-watt vacuum lamp, which has been superseded by gas-filled lamp of corresponding size at no greater cost, will also be eliminated. Some newer lamps such as the blue-bulb, daylight types, will be inserted in the schedules. The arrangement of decorative, signal, and switchboard lamps has been changed to make the schedules more intelligible for purchasing officers.

The Effects of Moisture on the Thermal Conductivity of Soils

With a Bibliography on the Heating of Cables

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It has been appreciated for many years that the presence of moisture in the soil surrounding underground cable was of assistance in dissipating the heat generated within the cable. But little was definitely known, however, of the exact changes in the thermal conductivity of soils caused by the presence of moisture. The following article shows that moisture plays a predominant part. The relative thermal conductivity of various types of perfectly dry soils, such as sand, clay, gravel, etc., covers a range from only one to two, while the addition of moisture increases the range to five times or more that of dry soils.

The article also includes a bibliography on the heating of underground cables, giving reference to 59 papers on the subject in English, French and German.

WITHIN recent years numerous ways have been suggested of working underground cables at increased load capacities. Some of the most promising methods have been:

(a) To decrease the temperature coefficient of dielectric energy loss by improving the quality of the insulation in high tension cables, thus allowing the cables to be safely worked at higher temperatures.

(b) To use a blackened sheath, consequently obtaining a better surface radiation to the duct air.

(c) To use forced ventilation of the duct air.

(d) To fill up the air space in ducts with water, compound, etc. In fact, anything that offers better heat conduction than still air.

(e) To carry away the heat by circulating water either directly through the ducts or through piping laid in the empty spaces of the ducts.

(f) To keep the surrounding soil thoroughly soaked with water, especially at hot spots, by laying porous tile piping just over the conduit.

(g) To use very porous ducts in conjunction with a porous pipe through the center of conduit cross-section so that water would gradually seep through and in rapid evaporation to the surrounding dry soil carry away a large part of the heat.

(h) To avoid all sources of external heat such as steam mains or undue absorption of sun rays. In this particular, the black surface of asphalt streets when fully exposed absorbs a great deal of heat from the sun.

(i) Lastly, and most important of all, to study carefully each individual conduit system and determine where the hot spots are and at what period of the year they need the closest watching. By some one or a combination of the above methods the heating at hot spots can be brought down to correspond uniformly with the rest of the conduit length.

The heat conducting path is a series path through the cable insulation, duct air, duct walls, concrete shell (if any) and finally into the surrounding soil. Obviously, the relative temperature drops through the different sections of the series path will determine the effectiveness of the above cooling methods. For instance, if the greater part of the temperature drop occurred from copper to outer surface of duct walls, or concrete, there would be little gain in saturating the surrounding soil with water. Some other method would then have to be used, such as outlined in sub-heading (c) or (e).

Fortunately, it is now fairly well established that in the average well constructed conduit line a very appreciable part of the total temperature drop, especially at hot spots is in the surrounding soil. Anything that increases the thermal conductivity of this soil is therefore worth considering. It is the purpose of this article to describe some thermal conductivity tests made on soils containing different percentages of moisture and to compare the results with those of other investigators.

Two previous investigators have published results of interest.[1] With dry sand and soils the agreement between their thermal conductivity values is good but there is a very great difference with wet sand and soils. Kennelly found that the thermal conductivity of wet sand was 2.4 times that of dry sand and that the thermal conductivity of wet sandy soil was only 1.3 times that of dry sandy soil. Teichmuller, on the other hand, found a corresponding ratio for sand of 5.2 to 1. Now, it is apparent that if Kennelly's results are correct artificial soaking of soil would not prove a very effective means of cooling. Tiechmuller's results are much more encouraging. Our work was undertaken to determine why there was such a large discrepancy in their findings and, in particular, to make a closer study of moisture effects.

To be presented at the 10th Midwinter Convention of the A. I. E. E., New York, N. Y., February 15-17, 1922.

1. "Heating of Copper Wires," Kennelly and Shepard, A. I. E. E., Vol. 26, 1907, pp. 969-995.
2. "Heating of Cables," Teichmuller and Human, *E. T. Z.*, June, 1906, p. 579.

Summary of Results

Profiting by the experience of the above investigators we were able to design our apparatus and conduct tests in a way that promised reasonably satisfactory returns. Before going into the details a summary will be given and a comparison made with the work of Kennelly and Teichmuller.

Thermal Conductivity of Sand. We first made a laboratory study of a representative unsifted builders sand. It was neither coarse nor fine but of medium texture and all pebbles of appreciable size were removed. When well tamped the amount of moisture required to saturate it completely was more than 15 per cent by weight but the sand would not hold this moisture long enough for test purposes, allowing some of it to drip gradually out of the test cylinder. From 9 to 10

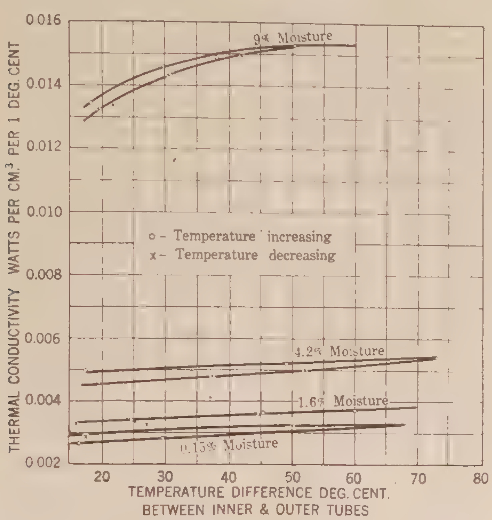

Fig. 1—Thermal Conductivity of Builders Sand

The curves represent the thermal conductivity of four samples of sand having respectively 9 per cent, 4.2 per cent, 1.6 per cent and 0.15 per cent of water by weight. The unit of thermal conductivity is defined as the watts flow of heat per square cm. per one deg. cent. temperature drop per cm. length.

per cent moisture by weight seemed to be the highest practicable amount. Teichmuller also found this to be true but Kennelly gives test data with 12. 7 per cent moisture for a fine sifted quartz sand, mesh 0. 25 mm. The much finer texture of his sand no doubt held the moisture better than the coarser sand we used. The practical lesson learned from this is that sand of the ordinary kind surrounding conduit lines cannot be expected to hold more than 10 per cent moisture without draining due to gravity unless water is continuously supplied either naturally or artificially.

After preliminary trials and checks of accuracy the curves given in Fig. 1 were taken on the builders sand described above. Each point on these curves represents a continuous run of about 24 hours. It required three months to complete the set of curves in Fig. 1 alone. The entire work extended over a period of more than one year. The water-jacketed cylinder used in this work is illustrated in Fig. 2 and will be dealt with in detail later.

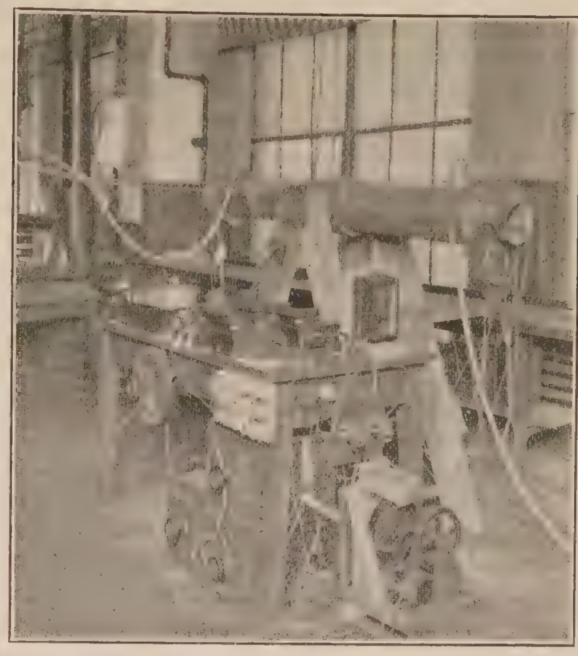

Fig. 2—Apparatus Used in Determination of Thermal Conductivity of Soils

The near end of the tube is open for the removal of the soil sample. The felt, and the ring, which holds it in place over the end of the tube, are shown hanging on a bolt just under the brass tube. The wood plug which fits in the end of the tube is shown on the corner of the table beside the contact-making voltmeter. Tests were made with tube in a vertical position.

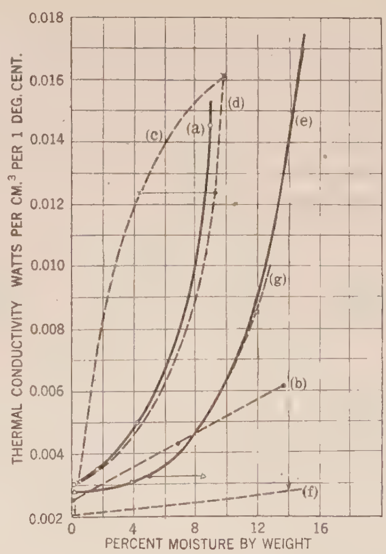

Fig. 3—Comparison of Thermal Conductivity of Sand and Soil as Measured by Three Different Investigations

(*a*) Clean yellow builders sand. (Author.)
(*b*) Fine white quartz sand, mesh 0.25 mm. (Kennelly.)
(*c*) Clean yellow sand. (Teichmuller.)
(*d*) Curve (*c*) reconstructed.
(*e*) Yellow sand clay soil. (Author.)
(*f*) Fine sandy soil. (Kennelly.)
(*g*) Normal or average sandy soil. (Teichmuller.)

The values in Fig. 1 were averaged and plotted as a thermal conductivity vs. per cent moisture curve in

Fig. 3 (see curve "a"). Now let us compare this curve with similar curves for sand obtained by Kennelly and Teichmuller. Kennelly used a fine grain quartz sand sifted through a 0.25 mm. mesh. His curve is given as (b) in Fig. 3. It would be expected, as will be shown later, that this curve should show slightly lower thermal conductivity than (a) because of the finer grained sand. With low moisture content (from 0 to 2 per cent) the agreement between (a) and (b) is reasonable but at higher percentage moisture the curves rapidly diverge.

Teichmuller used an ordinary sand, presumably similar to ours. His curve is given as (c). The thermal conductivity values agree almost exactly with ours at extremely low and high moisture contents. His intermediate value of 4.2 per cent is much higher however, giving his curve a different shape. The fact that the disagreement in only with the intermediate percentage of moisture content is significant in the light of our experience. We had a great deal of trouble in obtaining reliable data over this intermediate range of moisture content. The moisture had a tendency to migrate in the test tube, accumulating at one section and leaving another dry. These unstable conditions caused inaccuracies that were overcome only after several trials and a close study of "cause and effect."

If the 4.2 per cent moisture point on Teichmuller's curve (c) is ignored a curve can be constructed through the remaining two points that almost coincides with our curve (a). This reconstructed curve is shown in broken line as (d).

Thermal Conductivity of Clay Soil. After the measurement on builders sand were completed we tried a well pulverized yellow clay sub-soil but soon found it had a tendency to dry and cake around the heated inner tube because of the high temperature gradient here. The clay would "bake out" and cake at temperatures as low as 50 deg. cent. with a considerable decrease in its thermal conductivity. This same characteristic has been noted in the clay surrounding duct lines that have operated at relatively high temperature.

A mixture of 2/3 clay and 1/3 builders sand was then tried. This also had a tendency to cake in some instances but on the whole we were able to obtain some very satisfactory measurements. These are given in Fig. 4. The maximum percentage of moisture tried was 15 per cent by weight. The finely divided sandy soil seemed to hold moisture much better than the pure sand used in the first test, allowing this higher moisture content. The saturation point was higher than 18 per cent. A lower percentage of water was used to be on the safe side and to avoid instability of results by leakage of water during test.

The condition of the soil, the percentage and distribution of moisture, etc. were noted before and after each run. During the runs with 0.89, 3.87 and 15.0 per cent moisture all conditions remained quite stable throughout, but the run with 8.5 per cent moisture was disappointing. The moisture migrated to the outer radius of the tube leaving a dry shell of soil surrounding the inner heated tube. This point was therefore ignored in drawing curve (*e*) in Fig. 3. As can be seen from the curve the migration of moisture had the effect of lowering the 8.5 per cent point of thermal conductivity from 0.0056 to 0.00335 watt flow of heat per square cm. per one deg. cent. temperature drop per cm. length. (In brief, watts/cm.^{3}/one deg. cent).

Kennelly's curve for sandy soil is given as curve (*f*) in Fig. 3. It shows hardly any difference between dry and saturated soil and is likewise much lower in thermal conductivity than our curve (*e*). Curve (*f*) is similar in form to his curve for sand (*b*) and the relative proportions of these two curves fall in about the same order as our curves (*a*) and (*e*).

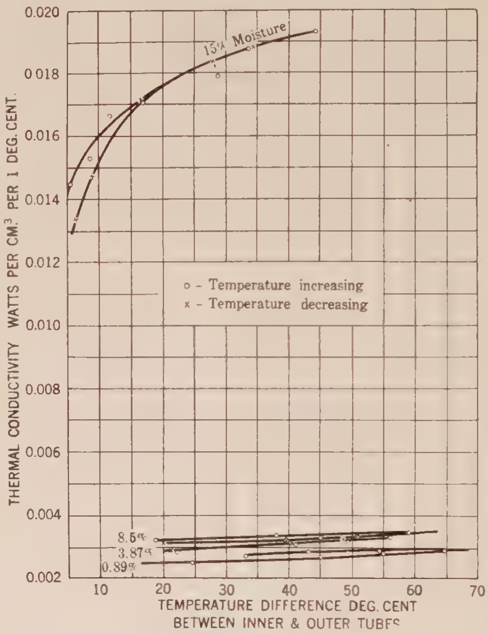

FIG. 4—THERMAL CONDUCTIVITY OF SANDY CLAY SOIL

The curves represent the thermal conductivity of four samples of soil having respectively 15 per cent, 8. 5 per cent, 3.87 per cent and 0.89 per cent of water by weight. The unit of thermal conductivity is defined as the watts flow of heat per square cm. per one deg. cent. temperature drop per cm. length.

Teichmuller published only one measurement on a soil which he designates as "normal" or "average" soil. It is presumably an average sandy clay soil such as usually found in trenching or excavating. His one measurement was made with 12 per cent moisture in the soil and using this as a guide we have drawn in a short section of curve (*g*) in Fig. 3 to show how closely it can be made to agree without corresponding curve (*e*).

On the whole, our results and Teichmuller's agree satisfactorily. We do not claim absolute accuracy for these results but when the conditions of test are carefully considered it would seem that they are more accurate than Kennelly's. All three investigators followed similar methods in that they made use of

concentric cylinders with the soil packed in between. The inner cylinder served as the source of heat and the outer was water-jacketed. End effects were corrected for in all cases. The real difference lay in the cross-sectional dimensions of the cylinders. These dimensions are tabulated below:

TABLE I

Investigator	Length of outer tube Ft.	Diam. outer tube In.	Diam. inner cylinder In.
Kennelly	9.1	3.06	0.128 & 0.045
Teichmuller	12.5	7.90	2.05
Author	7.0	6.00	1.00

In an investigation of this type the cross-section of soil tested is relatively small and because of this the aim should be to assure;

(1) That there is always good contact between the surfaces of the soil and test terminals and that the soil remains well packed.

(2) That the moisture in the soil remains uniformly distributed, especially around the inner cylinder.

(3) That the area of surface contact between soil and inner cylinder be a maximum, consistent with a reasonable volume of soil and diameter of outer cylinder.

(4) That the ratio between the diameters of outer and inner cylinders be a minimum, consistent with above conditions, thereby reducing the temperature gradient around the inner cylinder.

An examination of the dimensions in Table I will show that the test cylinders used by Teichmuller and the author fulfilled these conditions while Kennelly's did not. As inner cylinder Kennelly used a wire of 0.128-in. diameter. He checked this with a still smaller wire of 0.045-in. diameter and found that they gave the same results. The reason for this is easily explained. The high temperature gradient in the soil immediately surrounding the wires forced the moisture towards the outer cylinder, leaving a shell of dry soil around the wires. In both cases, then, he actually measured the thermal conductivity of an inner shell of dry soil and outer shell of moist soil, and since the inner shell plays the predominating part his measurements are more representative of dry soil than wet. His measurements on well dried sand and soils are more acceptable and agree quite well with those made by the other two investigators as shown in Table II.

TABLE II
Thermal Conductivity of Dry Sand, Soil, etc.

Material	Investigator		
	Author	Teichmuller	Kennelly
Clean yellow sand	0.00305	0.00310	..
Clean white sand (fine)	..	..	0.00256
Yellow sandy soil	0.00280	..	0.00284
Fine sandy soil	..	..	0.00209
Crushed quartz (mesh 0.85 mm.)	..	..	0.00337
Fine sandy gravel (mesh 0.5 mm.)	..	..	0.00290
Clean gravel	..	0.00436	..

The above tabulation would indicate that the dry thermal conductivity is somewhat dependent upon the size, shape and arrangement of the particles making up the material, or rather upon the volume of air interspaced with the particles. Coarse grained materials such as sand and gravel have better thermal conductivity than fine grained soil, just the opposite result that one might expect, but it is a known fact that within certain limits the percentage by volume of air in granular materials is inversely proportional to the size of the particles. We made no attempt to investigate this phase of the problem and it is pointed out simply as an interesting side light.

A comparison of the above tabulation of dry soils with the moisture curves in Fig. 3 will show that moisture is the predominating factor rather than the kind of material. The thermal conductivity of the dry soils covers a range from 0.002 to 0.0047 watt per cm.^{3} per one deg. cent., while the addition of moisture caused an increase to 0.017 and would have caused a still further increase if the test samples had been completely saturated. This would lead to the conclusion that it is immaterial what kind of soil surrounds a conduit line except in-so-far as the ability of this soil to absorb and retain moisture is concerned.

The investigation has proved conclusively that the presence of moisture in soils is very effective in conducting heat away from underground lines. Further study should be directed towards determining:

(1) Those soils that are best adapted to absorption and retention of natural moisture.

(2) Those soils that are best adapted to artificial means of moisture saturation.

Part II—Description and Details of Test

The first part of this article covers in a general way the more important and useful results of the investigation. In this second part the details will be dealt with.

When the work was first started the results were very erratic. As an illustration, some preliminary measurements on builders sand are plotted in Fig. 5. The temperature was raised and lowered in steps, as indicated by the arrows. In this way one or more "heat cyles" were completed and if the measurements and test conditions had been accurate and stable the "heat cycles" would have been narrow and uniform, similar in appearance to those in Figs. 1 and 4. Instead the measurements plot in a haphazard manner, especially those on very moist sand. By a process of elimination this erratic behavior was found to be due to:

(a) The high temperature to which the inner tube was heated, which caused the moisture to vaporize and then condense against the cold wall of the outer cylinder. A temperature of the inner tube of about 80 deg. cent. seemed to be the highest for accurate results.

(b) During the preliminary work we had no means of constant current control of heating element. Even

small fluctuations of current caused appreciable errors.

(c) The outer and inner cylinders were not connected together, electrically and grounded, at one end. Consequently when the sand was moist it furnished a resistance parallel to the inner tube and in attempting to measure the resistance of inner tube for determination of temperature an error was introduced.

(d) The inner tube used in preliminary work was of brass. The temperature coefficient of brass is smaller than that of copper and change in resistance, even when carefully measured with potentiometer, would not accurately indicate small changes in temperature. This trouble was eliminated by substituting a copper tube.

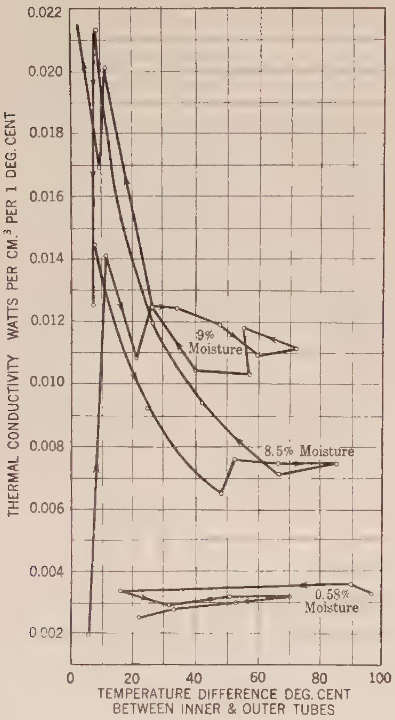

FIG. 5—PRELIMINARY MEASUREMENTS ON BUILDERS SAND

Showing the erratic results due to errors in testing methods. The arrows indicate the order of the respective readings.

The test equipment as finally developed is illustrated in Fig. 2. A dimensional sketch and a wiring diagram are shown in Figs. 6 and 7. A contact-making voltmeter held the heating current very steady. The cooling water for the jacket was taken from the city pipes and proved to be of very constant temperature (about 15 deg. cent.).

The resistance of the inner copper tube was carefully calibrated in an oil bath at different temperatures and the temperature drop across the soil under test was determined by subtracting the temperature of the inner tube, as measured by resistance, from the temperature of outer tube, measured by thermometers immersed in the water bath.

The general procedure was to place the concentric cylinders in a vertical position and fill the interstice with properly prepared soil, packing it down firmly during filling with a concentric disk spacer. In this way the inner cylinder was accurately centered. The cylinders were left in a vertical position throughout the heat run as we found this gave more satisfactory results. There

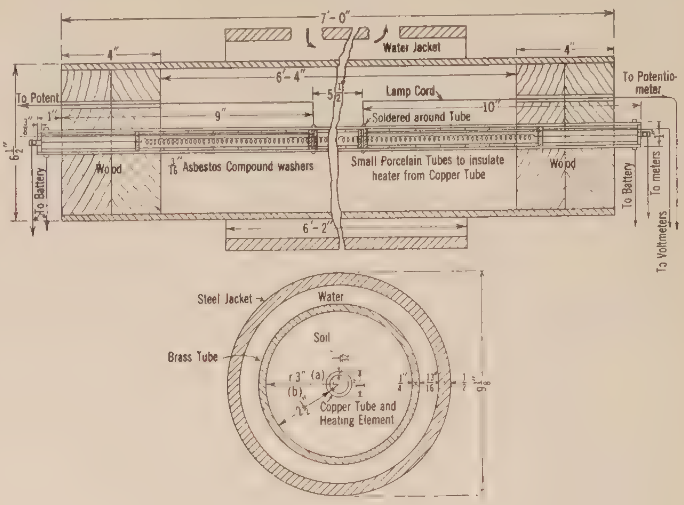

FIG. 6—DIMENSIONAL SKETCH OF TEST TUBE

was not only a better circulation of the cooling water but also the moisture in the soil would remain more uniformly distributed around the inner cylinder.

It required on an average about four hours to reach constant temperature conditions but for convenience and also to be on the safe side we usually let the run continue over night, taking all measurements the next morning.

Credit and appreciation are freely given to Dr. C. P. Steinmetz and Mr. J. L. R. Hayden for their valuable advice and aid in this work, and to Mr. D. A. Ballard for his untiring assistance.

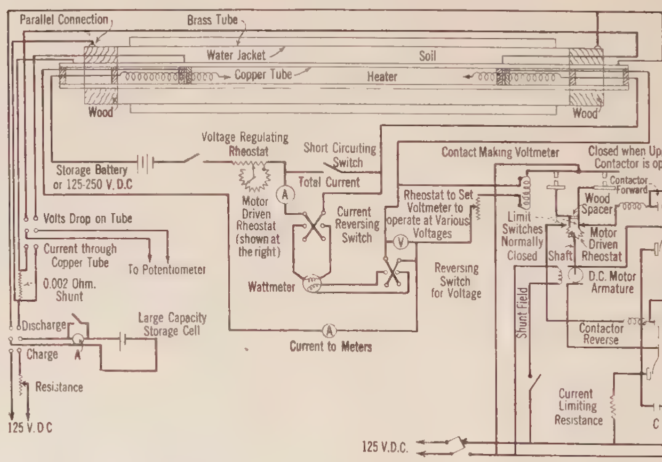

FIG. 7—DIAGRAM OF CONNECTIONS FOR APPARATUS USED IN THE DETERMINATION OF THE THERMAL CONDUCTIVITY OF SOILS

Appendix

HEATING IN UNDERGROUND CABLES

The foregoing laboratory work on the thermal conductivity of soils was completed a year and a half ago.

The results were not published at that time but were made available to engineering committees and operating companies actively engaged in a study of heating in underground cables. Publication at the present time is prompted by the Preliminary Report of the British Electrical Research Association on "The Heating of Buried Cables," which appeared in the *Journal* of the I. E. E., February, 1921. Recognition was made in this admirable and extensive report of the influence of moisture in the soil surrounding buried cables. No substantiating data, however, were submitted and it is felt that the present article contributes something in that respect.

Heating in underground cables has received a great deal of theoretical and practical consideration in the past and many articles have been published on the subject. During the course of our work a thorough canvass of the literature was made and a bibliography prepared containing reference to articles that throw light on the problem. The bibliography is given with the present paper in the hope that it may prove useful to other engineers.

Although this bibliography covers a great amount of work it is surprising how little progress has actually been made in placing the theory and practise of heating in cables on a practical working basis. In the writer's opinion this is due to a lack of coordinated and systematic effort. The problem is big and requires a really tremendous amount of coordinated work to place it beyond the preliminary stage in which it is now. The work undertaken by the British Research Association is a step in the right direction and should be supported by similar work in other countries.

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RADIO TELEPHONY IN THE LIFE-SAVING SERVICE

The Bureau of Standards has been cooperating with the U. S. Coast Guard Service in the development of a radio telephone apparatus to maintain communication between a motor life-boat and the shore station. The great importance of maintaining reliable communication between the shore and a boat engaged in rendering assistance to a wrecked ship is obvious. As most of such rescue work necessarily has to be performed in stormy weather, it is highly desirable to reduce to a minimum any apparatus above the deck level of the boat. No loose wires above, in, or under the boat are permissible, since these would interfere with the proper handling of the boat and the throwing of lines. For this reason, the installation of a small antenna of the ordinary elevated type, even a short distance above the deck would be very undesirable.

After considerable investigation, it was decided that a coil antenna offered the best prospects for success. A coil antenna need not be insulated from the earth to give good results. Two vertical pipes grounded at each end and having a connection made across their upper ends have been successfully used for this purpose, and several years ago two members of the Bureau's staff developed a coil antenna for use on submarines consisting of a single wire elevated a short distance above the submarine connected at each end to the metallic hull of the vessel. This constituted a single-turn coil antenna of which the hull formed a part, and successful communication has been carried on with a submarine so equipped.

A similar arrangement was adopted on the motor lifeboat for the Coast Guard. The boat on which the installation was made was 36 ft. long, driven by a gasoline engine, and was equipped with a heavy metal keel. The receiving and transmitting set was installed on the boat as far forward as possible and from it a wire was run forward connected to the keel, two other wires heavily insulated were run aft along the guards and connected to the keel. A particular kind of coil antenna was thus formed of which the keel formed a part.

This arrangement was satisfactory from a navigating point of view. The transmitting apparatus used at the station and on the boat were identical and consisted of a 5-watt radio telephone receiving set. The wave length used for transmission from the boat was 380 meters and that used for transmission from the shore station was 675 meters, the receiving equipment used included an amplifier employing three stages of radio frequency amplification and two stages of audio frequency amplification and was specially designed for the wave length used. This apparatus as installed on the boat was extremely compact.

On November 15, a demonstration was made at Atlantic City before representatives of the Coast Guard, and when the boat was 6 miles from shore good communication was maintained with the shore station. This distance is sufficient for the ordinary needs of the work, but if a greater distance is to be covered, it will, of course, be possible to use a transmitting set more powerful than the 5-watt set used in these tests.

The results of the tests were regarded as highly satisfactory, and consideration is being given by the Coast Guard to the installation of radio telephone equipments at a number of the more important stations.

On Deviations From Standard Practise in Lightning Arresters

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Review of the Subject.—*This paper is an endeavor to answer questions of practise and criticism of arresters brought out by an investigation conducted by the Protective Devices Committee.*

For the most part practise in lightning arresters is standardized. In fundamental principles there have been no changes for many years. Improvements in details, especially of construction, are still being made. A new arrester, the oxide film arrester, gets rid of the oil and electrolyte and avoids the necessity of daily charging, but fundamentally it is designed along the same principles as the aluminum arrester. The important principle is the electric valve action—there are but a few milliamperes of discharge rate at normal line voltage, but at abnormal line voltages the discharge current rise to hundreds of amperes. In answer to criticisms made by a few prominent engineers, it is maintained as fundamental that a large discharge rate for an arrester is an absolute essential. The burden of proof falls on those engineers who use arresters of low discharge rate. These arresters cannot discharge the dangerous lightning surges on overhead lines. Since there are lightning arresters of low discharge rate in apparently satisfactory use, an explanation for this anomaly is found in the use of insulators of low arc-over voltage. Either the lightning potential is relieved locally at the insulator or the resultant traveling wave is of too low voltage when it reaches the transformer greatly to endanger the insulation. Poor line insulation is not a solution of the problem of continuity of service. Why not save the cost of the useless lightning arrester?

The current in such a traveling wave is about two amperes for every thousand volts of lightning potential, 600 amperes for 300 kv. One to twenty-five ampere discharge rate of arresters has little effect in reducing the lightning voltage.

How many arresters should be used to protect a six-feeder system? It depends on the conditions of insulation in circuit breakers and the importance of continuity of service. According to the conditions discussed in the body of the paper, from one arrester connected to the busbars to seven arresters with auxiliaries are needed.

The use of no arresters is discussed from three standpoints. 1. If it is contended that lightning is not of sufficient voltage to cause damage. 2. If it is considered a better investment to put lightning arrester money into spare transformers. 3. If it is considered good practise to so highly insulate a transformer as to give it immunity from lightning. The conclusion reached is that each of these three arguments is dangerously faulty.

A new method of inspection of aluminum arresters is proposed. The experiments given in the paper show that the power factor of the cells examined is very sensitive to their condition. There are promises of effecting economies in overhauling aluminum arresters and of lengthening their life. Experiences are given with a 33-kv. arrester in service thirteen years without overhauling. The plates are still in good condition. The usual damaging deposits of decomposed oil on the aluminum film were prevented by using an initial rush of charging current great enough to throw them off. The electrolyte is partially exhausted in strength and needs changing. The discharge rate is still high.

CONTENTS.

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COMMITTEE SURVEY. For several successive years the Technical Committee on Protective Devices, Mr. D.W. Roper, Chairman, has voted to make a survey of practise in lightning arresters on transmission circuits (not distribution), but each year there have been other matters which took precedence.

Last year Mr. F. L. Hunt addressed a number of eminent transmission men with definite questions relating to specific cases designed to bring out views on advisable practise and to obtain adverse criticism. In general their answers represent standard practise. There are a few variations from, what seems to the writer, good practise. These variations will be discussed briefly by a presentation of definite reasons against them.

Object. Briefly the object of this paper then is to discuss: First, variations from good practise, and second, proper differences in standard practise, which will be treated under one heading; and third, improvements and economies in the maintenance of aluminum arresters.

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Differences in Standard Practise

Status of Lightning Arrester Practise. Established practise in lightning arresters is firmly based on sound scientific principles. There is still a number of unknown conditions and even the best developed devices fall short in certain ideal functions, but engineering judgment is found in every step.

Horn-Gap Arresters and Any Other Type of High Series Resistance. The initial discussion will be on the extremes of differences from standard practise, such, for example, as the use of horn-gap arresters and the practise of using no arresters at all. A brief review of some of the factors relating to arresters not of the electric valve type follows: (1) Horn gap with high series resistance, (2) with medium resistance, (3) with no series resistance.

(1) If a horn-gap arrester has a discharge rate of the order of 10 *amperes* it is *insufficient to relieve the potential of any dangerous induced lightning stroke.*

(2) If the discharge rate is of the order of 100 amperes the arrester becomes more protective in proportion but the amount of power taken by the arrester from the circuit makes both a heavy draft on the

generators and a difficulty in the design of the arrester. If it is designed with generous proportions to avoid overheating of series resistance the cost will be high.

Commenting on these factors: The power taken by a three-phase discharge of horn gaps with currents limited to 100 amperes on a 60-kv. circuit is about 12,000 kw. The usual time required for the arc to rise on a horn is about 5 seconds. No such discharge rate is used on these arresters in general because the resistance would be overheated by the power current which follows the lightning discharge. This energy would heat 600 liters (150 gallons) of electrolyte through 100 deg. cent. In so doing the resistance would reduce to a fraction of its initial value, due to the negative coefficient of resistance with the rise of temperature—a natural characteristic of electrolytes.

Commenting further on that persistent and inefficient device, the arrester of any type of low discharge rate, proof is herewith offered, in the following paragraph, that such an arrester has no value in discharging lightning.

Current of Traveling Wave: A traveling wave has an average current of two amperes per thousand volts of potential of the wave. For the argument following it is necessary to accept this numerical figure.

Proof that the approximate current in a traveling wave is two amperes per kilovolt of surge voltage follows.

The energy in a traveling wave is half electromagnetic and half electrostatic (see any standard work on this subject, for example such authorities as Bedell and Crehore, Steinmetz, Pupin, Berg).

Expressed in a formula

$1/2\, C\, V^2 = 1/2\, L\, I^2$ where the capacitance C and the inductance L of a single wire are taken for any chosen unit of length of the wave. V is the effective voltage and I is the effective current over the length of wire chosen as a unit. Or V and I may be used as the crest voltage and crest current. By simple transposition and cancellation the value of surge current I in terms of the surge voltage becomes

$I = V \sqrt{C/L}$ = approximately 2 amperes for No. 0, B & S. wire at an average height of 30 ft. (900 cm.) above the conducting surface of the earth.

The inductance L of a single wire with the surface charge on the earth is not a definite quantity, but its widest possible variation will not affect the final results greatly because this factor appears under a square root sign. The value of inductance L used was calculated on the basis that the electromagnetic field of a line wire extended to its image at a depth below the surface equal to the height of the wire above. The single wire inductance was then used. The actual inductance is more likely to be greater than less.

To illustrate how much effect the size of wire and its height may have on the surge current there were chosen two extreme cases. First, a large wire, one million circular mils, at an average height of 25 ft. (750 cm.) was used, and this increased the surge current of a single wire by only 18 per cent. Second, a small wire, No. 6 B & S, at a considerable average height, for the lowest wire 40 ft. was chosen. This lowered the surge current of a single wire to only about 90 per cent of that in the No. 0 wire at 30 ft. (900 cm.) height.

Significance of the Current in a traveling wave. If, then, a traveling wave on a transmission wire has an average current of 2 amperes per thousand volts (about 10 per cent more or less according to the dimensions, spacing, and height of wires), a lightning charge of 200,000 volts would have a current of 400 amperes in its traveling wave. This wave travels at 300,000 kilometers per second (184,000 miles a second), and an arrester which can draw off only 10 amperes from the 400 amperes, as this traveling wave rushes headlong into the insulation of the transformer, is not doing much to reduce the voltage of that wave. If by assumption the traveling wave has only 10 amperes of current its voltage is only about 5 kv. and is harmless to any transmission circuit.

The lightning arrester can take only a share of the current as the traveling wave reaches the point where the arrester is located. In other words, if the arrester is at any point on the line except at the ends the lightning current will divide into two parts—one part continuing along the line and the other part passing through the arrester to ground. The voltage of the traveling wave is not reduced even in proportion to the reduction of the current involved in the wave. This is because half the energy of the traveling wave is electrostatic and half electromagnetic.

In this argument is there anything subtle or vague or improbable? It requires only the acceptance of the figure of two amperes per kilovolt in the traveling wave and the well-known theory of the division of current at a bifurcation of the circuit. This same argument applies to any lightning arrester of any make which has a low rate of discharge. It puts the burden of proof for such American and European practise as high resistance and a jet of water used as a lightning arrester, on the engineers who advocate it.

Furthermore, all our laboratory experience shows that such a jet of water or any lightning arrester of low discharge rate has no appreciable value in discharging a traveling wave.

(3) If no series resistance is used the large arcs of short circuits which can be blown for 30 or 40 feet to other circuits call for large space of installation. Also there is the inevitable interruption of service to say nothing of other intrinsic dangers of short circuits. Still further, if separate grounds for the three phases are used for these horn gaps, the space between grounds becomes a menace to life. The arrester does not sustain the line voltage but throws it down to the ground. This menace increases with the potential and power of the circuit. As another objectionable feature, the earth contacts dry out under heavy discharge. The earth resistance may amount to any high value. There

are other objections to these short circuiting devices from a protective standpoint.

In going over these matters with an interested transmission engineer, he asked at this point the very pertinent question: How is it that a prominent engineer, whose judgment and veracity we both respect and who has no personal interest in the manufacture or sale of lightning arresters of the horn gap type, could install horn-gap arresters of comparatively low discharge rate on his circuits and honestly report successful operation?

In answer, there might be several ways that this condition could come about. As an illustration, if the insulators on a transmission line have an arc-over voltage of the order of say 120 kv. and the power voltage is 60 kv., lightning could not induce on the line more than double the normal line voltage without spilling over an insulator and relieving itself locally at the point on the line nearest the stroke between cloud and ground. The traveling wave is only about 70 per cent of the arc-over voltage of the line insulator, due to the

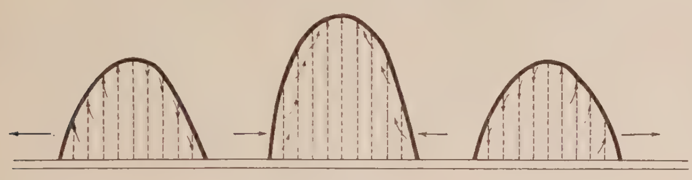

Fig. 1

Traveling wave to the left, one-half of the initial energy. Initial charge which is momentarily stationary. Traveling wave to the right, one-half of the initial energy.

lightning charge breaking into two parts which travel in opposite directions from the place of maximum induction (Fig. 1).

The insulation of the transformers is designed to withstand a test of double voltage for a minute. The only danger of this traveling wave lies either in a steep wave front which would damage the insulation between end turns, or in some remote possibility of an internal resonance in the transformer coils. The chances of damage are very slight. Then arises the question when such a condition of line insulation exists—why even go to the expense of the useless horn-gap arrester? An engineer may have inherited these conditions of low insulation on the line and may be making the very best engineering practise out of a bad situation, keeping very properly in mind the dividends to the stockholders. We venture to say, however, that this same engineer would not recommend low dielectric strength of insulators or a revival of the once tried practise of placing horn gaps at every insulator. The best practise today is in the direction of the highest reasonable factor of safety in the spark potential of the insulators.

Another way in which the user of a horn-gap arrester of low discharge rate could escape without loss of insulation of the transformer is by using a horn gap without resistance, in parallel with the resistance type. In this case the dielectric strength of the insulators may be very high and the voltage of the traveling wave may be at a damagingly high value, and yet damage to the insulation of the transformer may not be evidenced. However, it is not a solution of the problem, because the primary object of a transmission system is to sell and deliver power. The power service is interrupted by the short circuit of the horn gap.

The Effect on Practise of the Demands of Continuity of Service. The foregoing statement of service brings us immediately to a difference in arrester practise between engineers of different systems in which they can all be right. At one extreme there is the demand of service so slightly emphasized as to make it permissible to disconnect the power from the line during lightning storms. If visual observation and storm detectors could be relied on there would be little need of lightning arresters under a condition of this kind. Any one might take a chance without being criticised.

At the other extreme is the requirement of service illustrated by the Edison companies where one interruption in ten years is considered a calamity. In between are all grades of requirements brought about by the supply of power to such industries as paper mills, mining pumps, weaving mills, and manufacturers of any material which requires a continuous movement of the machines from the beginning to the end of the piece being manufactured.

There is another factor relative to the installation of an arrester of low discharge rate which has not been sufficiently emphasized, namely that no matter what type of arrester is installed the expense of installation is always considerable. If the expense of the installation is to be undertaken, why not add a little more and get an effective discharge rate?

A large concern whose business is enhanced by perfect service of its main apparatus in the form of generators, transformers, motors, lamps, etc. cannot argue the case for a cheap ineffective lightning arrester and build up a business in this line based on incomplete and immaturely considered experiences.

The foregoing argument does not take into account the sincerity of research engineers who have collected and analyzed voluminous data for many years and have concluded that it is an economic waste to the art of transmission to invest in arresters of low discharge rate as now installed. To any one company the futile expense may not be damaging but the aggregate loss for the country over is very considerable. The idea of giving a new arrester a trial indicates an admirable progressive spirit. But to do this without considering the intrinsic factors or the characteristics of the arresters entails unnecessary waste. It is one of the objects of this discussion to present reasons for present practise and thereby give the dissenter an opportunity to present his side in open forum. The dissenter also owes it to the art to set us right, if we are wrong, and thereby effect a still greater saving in investment.

The Practise of Using No Lightning Arresters. We now pass on to another extreme of practise, namely, the system which operates without any lightning arrester. There is only one such overhead system of importance that I know of. What penalty it is paying for this practise is not yet fully determined. What financial losses are entailed? What kind of service is given? A review of the evolution of this condition may be valuable in preventing some other system from attempting the same practise without having the same conditions. The transformers on this system were rewound with extra-high insulation at a very considerable expense. This is the first and most important item. Aluminum lightning arresters were used in the earlier days, the neutral was non-grounded, and the practise of keeping the power on the circuit regardless of the conditions did, in one case I know of, hold a persistent arcing ground for ten hours. Naturally an aluminum lightning arrester was destroyed and the remarkable feature was it lasted the ten hours. At that time the engineer argued that he was willing to sacrifice the arrester to maintain the service, but he lost both the arrester and the service. Under this practise one arrester after another disappeared and there is no desire on the part of a manufacturer to sell more arresters. There are certain lines of argument that one may follow regarding this installation. (1) It may be contended that the lightning is not of sufficient voltage to cause any damage; or (2) it may be considered a better investment to put the lightning arrester money into spare transformers; or (3) it may be considered good practise to so highly insulate a transformer as to give it a high degree of immunity from lightning.

Considering these three possible arguments in the order given above, first, that the lightning may not be of sufficient voltage to damage the insulation—if the lines are highly insulated—one can only say, Alas! Tests made in the laboratory on coils representing end turns of a transformer have demonstrated the ease with which a spark may be formed between adjacent turns puncturing the insulation. To note this tendency on transmission lines the simplest method is to place a spark gap in parallel with a choke coil of comparatively few turns. During lightning storms frequent sparks will take place. Another situation where this effect is shown is the frequency of puncture of current transformers by traveling waves. Many such experiences have led to the conclusion that traveling waves, especially of steep wave front, will cause punctures between turns of the end coils of transformers—certainly they do in extreme cases of high voltage. This would require the best protection obtainable. To be sure, a single puncture of this kind does not, in general, cause short circuit, but the successive sparks may be cumulative in their effects, punctures being made at different points until the conditions are right for holding the arc. Small transformers and very large ones are more likely to fail than intermediate sizes due to the distribution between layers or between turns. More technical data on this subject are needed and are being collected.

Second, the spare transformer method of caring for dangerous lightning strokes needs comment. It is not necessarily a poor engineering proposition. On the contrary there are conditions which make it acceptable. As an example of an installation of a step-down transformer, if the requirements of continuity of service are rigid, if the transformers are of low kilowatt capacity and of high voltage, it is difficult to figure economy in an investment in a lightning arrester. Arresters have a way of mounting in cost as the required voltage of the circuit is higher, regardless of the kilowatt capacity of the transformer. We have given this matter attention for several years without being able to evolve a satisfactory arrester. Such an arrester must have the characteristics of low cost, high discharge rate, independence of attention, and practical indestructibility.

Admitting then there is now no acceptable standard practise for application of lightning arresters for high-voltage transformers of low kilowatt capacity, let us turn attention to those of higher capacity such as are installed in power stations and principal step-down stations. Will the service demands permit an interruption while a spare transformer is shifted from one station to another? Shall a spare transformer be ordered for each station? Shall it be single- or three-phase? If a lightning storm should damage two single-phase transformers out of the four available, would the loss of revenue, to say nothing of the prestige, far exceed the interest and depreciation on one set of arresters at this point—or even several sets of arresters included in a proportional charge? Is it worth the price to risk a possible cumulative damage to the insulation of generators and transformers by occasional heavy discharges without arrester protection? Where the answer is yes, the case is settled. Every transmission engineer must find a balance between the risk of no protection and the cost of failure without protection. The primary question for self-interrogation in any particular installation is: What will it cost in loss of revenue, in time, in repairs, and in prestige to have a failure of one, two or of all three phases? Lightning storms average up if the effects of enough of them are taken into account. The chances of a stroke near a station are not very great. In lightning-infected countries one must in general by pure chance expect, some time, a progressive thunder storm which, instead of crossing the lines at an angle, runs longitudinally with it, with practically every stroke effective in producing a high-voltage surge on the lines or in the station. One can go several years with hearty self-congratulation instead of lightning protection and finally meet a longitudinally traveling Waterloo.

It has been and still can be properly argued that

many or even the majority of discharges of lightning arresters are unnecessary as the charges are harmless. This is true where the gaps of the arresters are set at a spark voltage only slightly above line voltage. But such an argument does not decrease the intensity of the minority of discharges, nor does it prove that arresters are not necessary for protection for the lesser number of heavy strokes or that it is good judgment to do without arresters entirely.

To summarize some of the points: Arresters may be dispensed with (a) if there are no lightning storms and no surges on the lines; (b) if the insulation of the power apparatus has a higher factor of safety than the line insulators (leaving a chance of damage by a stroke near the station); (c) if there is available a good detector of lightning as it approaches the lines and the circuit breakers are opened before the storm breaks anywhere over the aerial line; (d) if the transformers are of such low kilowatt capacity that the relative cost of the arrester is above the economical dictates of risk and replacement of damaged transformer Loss of service to the customer and the interruption of the main power service by accidental failure of a small power transformer must at present be carried on the debit side of the book value of this customer's payments. At present the lack of acceptable solution of this problem is interfering with the installation of small-power transformers on high-voltage circuits. This is a condition the manufacturer of transformers regrets as much as the power company and is as eager to correct; (e) on underground systems with grounded neutral, arresters may be used sparingly.

Third. As to using thicker insulation instead of lightning arresters—thicker insulation on the transformer turns of the coils engenders more difficulties in extracting the heat from I^2R losses and lessens the kilowatt capacity of the transformer. Since it seems impossible to put on enough insulation to prevent all lightning troubles it has become standard practise to use a reasonable amount of insulation and employ a lightning arrester. The arrester seems necessary anyhow for occasional extreme voltages.

Taking up one of Mr. Hunt's questions relative to the installation of lightning arresters on a circuit consisting of six feeders leading out from a bus—he has received the answers that, at one extreme of practise a lightning arrester should be placed on each one of the six outgoing feeders; at the other extreme, either one lightning arrester on the bus is recommended or none at all if the feeders are cables. If the feeders are important, the lightning frequent, the service demands rigid, the six arresters are desirable. Even greater protection may be necessary. If, on the other hand, the demands of protection are not great, then one or two arresters on the busbars would be sufficient. Two arresters are recommended when it is important to have one as a spare. One arrester of high discharge rate reduces the risk to a small value. However, if this practise of using one arrester is followed there are two important things that must be done at the same time: First, the current transformers must be shunted by bypass gaps; second, since the arrester is on the generator side of the automatic circuit breakers the circuit should be protected against accidental short circuit by suitable fuses on the arrester.

Engineering judgment must be used and all the factors of protection taken into account in order to decide how many lightning arresters to install on these six feeders and how to place them. I shall now take another hypothetical case, not unknown in practise, in which even the installation of six arresters does not give good protection. Suppose the line insulators have an unusually high factor of safety against lightning potential. This is good practise. Money could scarcely be better invested in a transmission line. However, it influences the practise to be followed in lightning arresters. The higher insulation of the line prevents the local relief of induced lightning strokes and therefore carries into the station unusually high lightning voltages. The choice of high factor of safety in the insulators leaves the standard circuit breaker, for example, and the current transformer, for another example, relatively poorly insulated. It is an easy matter for the transmission engineers to select a current transformer of higher voltage than usually demanded. But it is not a matter that can be so easily taken care of in the circuit breaker. The circuit breaker is a combination of a porcelain bushing, steel parts, and metal mechanism which has been standardized and is expensive and presumably already in use in this hypothetical instance. The porcelain bushings cannot be either changed or increased in dielectric strength. To place a single lightning arrester on the bus without any protection on the feeders would be tantamount to inviting the lightning to jump over the bushings of that very important protective device, the circuit breaker, and thereby invite a calamity of serious nature. Such a condition of high insulation on the line and low insulation in the breaker demands not only a lightning arrester on each feeder but also a considerable inductance in the form of choke coils between the line and circuit breaker. It also demands for the best conditions of protection that a lightning arrester be placed on the bus of the station in order to discharge the quantity of electricity which gets through the choke coils of the feeders during the brief period that most of the lightning charge is finding its way to ground through the lightning arrester. A choke coil cannot choke back the traveling wave without absorbing some of the charge. Such an absorbed charge cannot, without reflection of the wave, return to the lightning arresters on the feeders any more than a bullet can return to a rifle barrel after it has passed the muzzle without rebounding from the target. The analogy is complete. Here, then, is described the condition where if the engineer were laying out an

installation in the first place he could have the choice of higher voltage circuit breakers and practically few lightning arresters or lower voltage circuit breakers and a full complement of protective apparatus. Like any other engineering proposition, all the parts must be designed to work together.

The casual critic who holds the weakness of lightning arresters reponsible for the interruption of service during lightning storms is misled by the name of this device, to wit, "lightning arresters", and is in utter confusion regarding their function. A lightning arrester is designed to protect end coil insulation from puncture and any other exterior insulation at the point where the arrester is installed. If it protects the service it is only a secondary matter due to its protection of the insulation. The most prolific cause of interruption of service on overhead lines is arc-overs of insulators by lightning at points distant from arresters. The lightning arrester has no function to prevent such an occurrence. The best protector for accidental arc-overs of insulators is the arc suppressor—a device not yet sufficiently perfected to be used in standard practise.

Prophecies. Closing this part of the subject,—this paper is not intended to give completely even the principles of protection, to say nothing of the theory and practise. It strikes a few high spots raised by the investigating committee. There must be the admission of lack of perfection in the art of protection. This admission is somewhat offset by renewed activities in researches and developments since the close of the war. It may be pertinent (although risky to the prophet) to say we can see the possible routes by which a high degree of perfection is to be attained. This statement is virtually saying that more than half the final spurt is run. Preventing interruption of service by arc-over of insulators will do away with the cause of the majority of interruptions on overhead circuits.

To clean up the final residue of failures and troubles will require the most hearty cooperation between the operating engineers and the laboratory specialists who spend their time studying the voltage phenomena and the characteristics of insulations—and will call for a power of analysis not yet in sight. For long-distance transmission the goal sought is the degree of continuity of service given by the Edison companies in the larger cities. It is possible and must be reached.

The Aluminum Arrester and Criticisms of Film Theories

One of the broad fundamentals dwelt upon in the foregoing pages is the need in an arrester of a high discharge rate, a rate comparable with the currents in lightning surges. It is not necessary to master the fine details of theories of films to determine if an arrester has this quality. Place a single cell of two cones for a unit period of one to four cycles on a 600-volt a-c. circuit of sufficient power to maintain the voltage. Does the current rise to several hundred amperes? Therein is the answer without any theory. An oscillograph gives full data on what takes place. It will give the answer, "No", to the question, "Does the arrester short-circuit the voltage?" The ballistic throw of a large ammeter, not too much damped to respond to a sixtieth of a second, will give an indication of large current flow.

Inspection and Repair of Aluminum Arresters. The question of overhauling the aluminum arresters is by far the most serious criticism that has been made of arresters. The whole subject of inspection and repair is under reconsideration. The following investigations show that the power factor of the aluminum cells, either as individual cells or as a whole stack, may be a desirable method of inspecting the condition of an arrester before deciding to disassemble the parts. The use of power factor is new and, furthermore, it is well-known that the effects given by aluminum cells, such as variations in current, wattage loss, and power factor, are factors of wide variation, depending upon the quality of the aluminum, the nature and temperature of the electrolyte, the wave form, and the like. Some cells have shown deterioration by the presence of an abnormally high charging current. (Unfortunately deterioration is not always accompanied by higher charging current.) Cells have also shown deterioration by the value of the watts loss. So far as the recent investigations have gone the power factor method seems to be the most generally reliable indication of the condition of the cells. Deductions drawn from the measurements of power factor are comparatively new and, while the figures given are actual test data, it will require a wide experience to determine on dependable instructions for making the inspection. With these words of caution against the interpretation of these favorable data as final, some excellent results of these investigations will be briefly reviewed.

The Adirondack Power Company had two 33-kv. arresters handy and of promising interest. Reliable information was received that they had not been overhauled since installation, thirteen years ago. The first point of interest was the conclusion that either the arresters must be in deplorable condition or else there was some good way of avoiding frequent overhauling. We were in search of deteriorated aluminum cones and would have been pleased to have found this condition. The operating engineer may be more pleased by the fact that the aluminum surfaces were not corroded or eaten at the contact line of oil and electrolyte. Of course, thirteen years of daily charging had partially exhausted the electrolyte. Although new electrolyte was needed the discharge rate of each cell on 600 volts was several hundred amperes, showing that the arrester still gave good protection. It was still in good operating condition. The oil was somewhat modified by the oxygen and hydrogen freed by electrolytic action, but was not in a condition risky for operation.

The second point of prime importance was the fact that the charging currents of the several phases of the arrester as read by ammeter were near normal. On the west arrester the currents were slightly below normal. On the east arrester they were only 9 per cent to 27 per cent above the recommended normal value. Wave shape, quality of aluminum, and quantity of electrolyte will make this much difference. Since other tests were made which showed the arrester needed overhauling, the results indicate the unreliability of depending on current readings alone to determine the best time to overhaul. The spark at the beginning and end of charging was snappy and normal. Here, then, was an arrester giving safe and satisfactory operation, but which had reached a point of exhaustion of electrolyte, marking the period most desirable to overhaul.

A new method of simple electrical test was adopted, which shows this deteriorated condition of the cells so strongly that it is more than 300 per cent greater than with new cells. The method consists in measuring the wattage and voltage in addition to the charging current and calculating the power factor. For example, one stack of cones on the east arrester was removed for other studies. A stack of new cones replaced it. The power factor of this new stack was 14 per cent. The three remaining stacks had power factors of 42 per cent, 46 per cent and 47 per cent. (three times normal).

The west arrester with charging currents less than normal had power factors higher and lower than the east arrester, 50 per cent, 44 per cent, 43 per cent and 27 per cent respectively for the four legs. Since no inspection of these cells has been made, other than indicated by these measurements, the physical condition of the cells of the west arrester is not yet known.

Twenty-one cells of the stack taken from a tank of the east arrester were given individually a detailed study. Such measurements were made as: (1) Initial current rush at 250 volts impressed, (2) normal charging current, (3) watts loss, (4) discharge rate at 600 volts impressed, (5) rate of dissolution, (6) power factor, (7) thickness of film, (8) restoration of normal film, (9) resistance of electrolyte, (10) quantity of electrolyte per cell, (11) concentration of electrolyte, (12) insolubility, if any, of precipitate, (13) exhaustion of electrolyte, (14) physical appearance of films and degree of corrosion of the aluminum surfaces, (15) sludge at surface of electrolyte, (16) sludge deposited on the free surface of the cones, (17) also sludge in the body of the oil, and (18) electrolyte in bottom of tank and (19) electrolyte in the oil.

Too much attention to the many details at the present moment will tend to obscure a few important results. In general the individual cells varied in their conditions. Most of them had low charging current. Three of them had currents three times normal. Three showed considerable dissolution of film and required special attention to reform them.

All of them showed relatively high power factor. The highest was 88 per cent. The lowest was 36 per cent. Several ran in the sixty-percentages. Most of them were in the forty-percentages, around the average value for the stack.

Attention was given to the typical groups of cells to determine if they could be brought back to the normal condition of new cells without disassembling. It was done simply and quickly. Electrical treatment (momentary high current rush) was given to the films and the old electrolyte was replaced by new. The power factors returned to the value for new cells. After thirteen years of continuous operation these particular cells were made as good as new without treatment with alkali or acid and without factory formation of film.

As depreciation goes on all apparatus, this record is satisfactory. So far as any one can see the aluminum is good for several decades more. It is desirable to renew the electrolyte more often than once in thirteen years, but apparently no harm has come from this long period of use. Why can not this record be extended to all installations of arresters? We can see no reason to the contrary at present. The materials in the arrester (aluminum, electrolyte and oil) seem to be the same as the average of all other arresters. The only apparent difference from standard practise is in the method of charging the cells each day. When this matter has received thorough investigation and repeated confirmation has cleared away all doubts, it will be time to make definite and final recommendations.

Before this longevity can be brought about there are many arresters in service to be overhauled. There are conditions where films are to be removed as the easiest way of removing impurities on the surface and in the cavities of the aluminum produced by the action of the modified oil. To send aluminum cones back to the factory with the expenses of express, factory labor and chemicals, and loss of time, is a serious factor and an endeavor is being made to develop methods which will avoid much of it in the future. The developments and early installations were made with aluminum formed without elaborate dipping tanks, water cooling and automatic regulation. In the routine standardization of factory processes the early art of formation was forgotten. These methods will be revived and improved so that a properly trained man may be able to reform films without loss of time at the place of installation.

To determine what approximate conditions were involved, single cells were experimented upon. The films were removed and the surfaces of the aluminum thoroughly cleaned, involving about a minute of time. After the cones were washed, the major part of the new film was put on, by the most rapid method known, in about a minute. The temperature of the electrolyte rose about 30 deg. cent. The finish was then applied by the normal charging method. Several minutes of application were used.

With suitable chemicals, machines and equipment

this work may be done in the field of operation. The standard electrolyte contains a germicide and two organic chemicals which make it less suitable and more expensive for forming films than "forming" electrolyte which does not contain them. The electrolyte used in forming is more or less exhausted in the process which involves considerable electrochemical energy. This exhausted electrolyte, therefore, must be replaced by fresh electrolyte after the new films are formed.

This is not the time or place to give the detailed instruction for the proposed methods of inspecting and overhauling. If it is found desirable after further experimentation, it is planned to give instruction elsewhere—in the *G. E. Review* and in pamphlet form.

The new power factor method of inspection of the condition of an aluminum arrester may be put into the hands of any one familiar with the handling of indicating instruments around a high-tension three-phase system. The methods of renovating the films at the place of installation is simple enough to anyone accustomed to manufacturing and laboratory work. There are a few things to be scrupulously avoided. There are corrosive chemicals to be used. Furthermore, an equipment is necessary to do the work economically. There should be two trained men, such things as standard electrolyte, forming electrolyte, acid, motor-generator, standard cells for comparison, exchange racks, "forming" racks, suitable meters (ammeter, voltmeter, wattmeter), potential transformer of variable voltage, jin poles, block and tackle, rapid filter, graduates, suitable glass and rubber tubing, motor-operated contactor and so on.

There will not be enough work on any one transmission system to keep an outfit busy and to retain experts properly trained to carry on the work rapidly with accuracy and judgment. The long intervals between overhaulings allow memory to play tricks in the performance of the method. Changing personnel and positions are other factors which deprive the operator of trained men. If it could be brought about, the most economical results would be obtained by having experts with their outfit go from one system to another devoting their time to this particular work. Will a number of transmission companies share the initial expense of apparatus? With the conditions compatible with success the greatest pains will be taken by the manufacturer to give experts instruction and experience, to help them train their judgment, and to inform them on the proper instruments, apparatus, and methods to employ.

To summarize the possibilities relative to overhauling aluminum arresters, the promises are: More accurate and definite methods of inspection of the arrester will soon be made available. Unnecessary overhauling may be decreased. Longer periods between overhaulings may possibly be brought about by slight changes in methods of charging. Longer life of the arrester may also be attained. The actual cost of overhauling will be decreased. The cost per annum will be greatly decreased. Deteriorated plates may be reformed at the place of installation.

Bibliography. A complete bibliography is under preparation for publication later.

IMPROVEMENT IN RARE-METAL THERMOCOUPLES

Tests made by the pyrometry laboratory of the Bureau of Standards early in 1921 revealed the fact that many of the platinum-rhodium thermo-couples found on the American market were subject to large changes in indication after long continued exposure to very high temperatures. The constancy and reliability of these couples is a matter of great importance in view of their widespread industrial application for the measurement and control of high temperatures, and because upon correct functioning of these thermo-couples depends the quality and physical properties of many manufactured products.

The wires from which these thermo-couples were made were obtained from two sources, one American and one British. The tests showed that the former were of satisfactory purity for the use to which such couples are applied. They satisfactorily met all industrial requirements as to constancy and reliability if properly protected by well-known methods of insulation.

The British refined metal and alloys were found to be subject to large changes in their indications because of exposure to high temperatures. Chemical and spectroscopic tests revealed the fact that the trouble was due to the presence of several tenths of one per cent of iron in the platinum-rhodium alloy wire. The platinum wires, on the other hand, were found to be of high and satisfactory degree of purity.

The facts developed by these tests were immediately communicated to the firms engaged in refining the metals used for thermo-couples as well as to manufacturers of pyrometers who were employing them in their pyrometric installations. As a result of these tests, the British firm determined to improve its product and immediately took up the problem of producing new platinum-rhodium alloys free from the presence of iron or other impurities. Samples of their improved wire were submitted to the Bureau for test a few months ago, and the results show the new couples to be eminently satsifactory. Therefore, at the present time purchasers have a choice of two makes of wire either of which will prove to be satisfactory.

Full details of the life tests of all the thermocouples included in this investigation, as well as the chemical and spectroscopic tests made on the wires entering into their construction, have been submitted for publication in *Chemical and Metallurgical Engineering.* This work has resulted in a marked advance in reliability of high temperature measurements, since it has brought about the general use of materials of sufficiently high purity to remove an important cause of variations in thermo-couple indications.

The "Indumor"

A Kinematic Device which Indicates the Performance of a Polyphase Induction Machine*

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Subject of the Paper.—*A kinematic device is described and illustrated which represents the vector diagram of a polyphase induction machine. The parts are made to assume at will different positions corresponding to different loads of an induction motor or generator. The primary and the secondary constants, the magnetizing current, and the core loss, are also adjustable at will. The device permits the visualization of the performance of an induction machine and can be used for a study of a given machine or for a selection of the constants to give the desired performance characteristics of a new machine. The input, output, torque, speed, power factor, etc., can be read off on the device as in an actual brake test.*

The kinematic connections consist mainly of generalized proportional dividers and of parallel tongs, so combined as to satisfy a system of simultaneous vectorial equations which represent the properties of the machine. Further applications of the device to polyphase commutator motors are suggested.

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INTRODUCTION

The Meaning of the Word "Indumor." An abbreviation of the words "induction motor."

What the Indumor is. A combination of movable and adjustable bars (Fig. 1) which can be set to represent to a certain scale a vector diagram of voltages, currents, m. m. fs. and fluxes in a polyphase induction motor or generator of any desired constants. The parts of the device are kinematically so constrained that the diagram set correctly for one load remains correct at any other load.

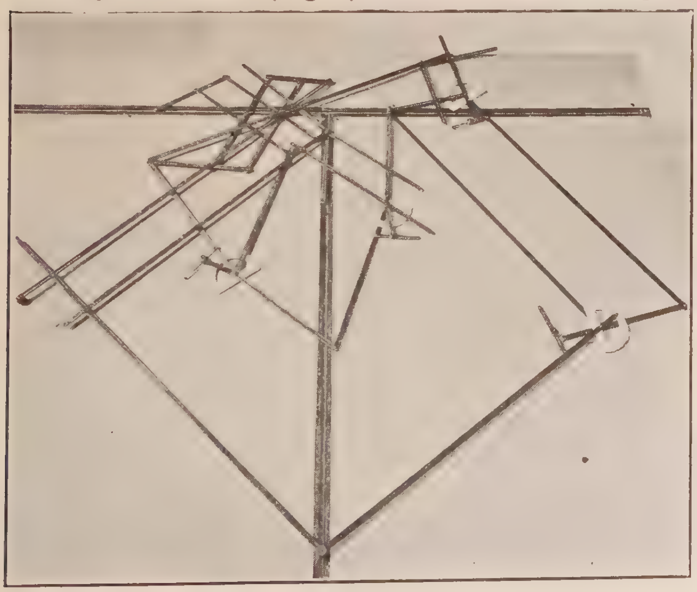

Fig. 1—The Indumor

The Purposes of the Device. (1) To enable a designer to select the best electrical constants and to "test" an induction motor or generator before it has been actually built. (2) For some applications to take the place of an involved analytical theory; it is often difficult to see the effect of separate factors upon the performance characteristics, and it takes considerable mathematical skill to deduce the equations of the various loci. (3) For some purposes to take the place of the circle diagram which becomes quite complicated when the primary resistance is taken correctly into consideration. (4) To add the judgment of the eye and the skill of the hands to the purely mental ability in selecting the constants of a machine for a desired performance, or in judging the characteristics for assumed constants. (5) To enable an investigator or a student to familiarize himself with the machine as if he had one available for tests. This is of particular importance with large machines for which no facilities may be available for testing.

The Performance Curves that the Indumor Enables One to Draw. Current, torque, speed, slip, input, output, efficiency, power factor, and magnetizing current. These may be obtained just as easily at a constant applied voltage as at a voltage which varies in any desired manner.

The Factors Which May be Taken into Account and varied separately at will in the Indumor. Per cent magnetizing current; per cent primary and sec-

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ondary resistance; per cent primary and secondary reactance; core loss; friction.

Limits of Rating and Output. Like any other graphical device, the Indumor requires certain scales to be chosen for each particular problem. A convenient scale has to be selected for amperes, and another for volts. The device can represent the performance of a fractional horse-power motor as well as of one whose output runs into thousands of kilowatts; of a 110-volt machine as well as of one wound for 11,000 volts. As in any graphical device, there are limitations due to a finite length of the links. With a certain setting the device may give an accurate performance say between no-load and 1.5 times the rated current. If a heavier overload is desired a smaller scale may have to be chosen for amperes.

B. General Description of the Indumor

The first complete Indumor was built in the shops of Cornell University during the summer of 1921 and is shown in Fig. 1. The same device is shown as a single-line diagram in Fig. 8. It is made of flat steel bars, not over one cm. wide and a few millimeters thick. The lengths of the principal members, between centers, in centimeters, are shown in Fig. 8. Some bars are of constant length, others are of adjustable useful length, holes being drilled every few millimeters. Most bars are connected to each other by means of pivot joints; others are set at a constant angle to each other by means of the protractors clearly seen in Fig. 1.

The device is assembled on a table provided with two grooves, at right angles to each other. The ends of some bars are constrained to move in these grooves. Different bars have to be placed in different horizontal planes to enable them to cross each other without interference. In Fig. 8 the bars nearest to the table are marked 1, those immediately above them are marked 2, etc. The particular sequence selected is not essential since the device is intended to represent a vector diagram in a plane.

A detailed description of the functions of different parts is given below in connection with the theory of the Indumor. It suffices to state here that the device is set for chosen design constants at a certain load. The setting is done by selecting suitable scales for volts and amperes and adjusting the lengths of a few bars and the angles accordingly. The Indumor then represents a set of four simultaneous vectorial equations which together characterize the machine, viz.:

(a) The primary electric circuit;

(b) The secondary electric circuit;

(c) The main magnetic circuit;

(d) The relationship between the induced e. m. f. the flux.

After having been properly set, the kinematic combination becomes a *system with one degree of freedom,* that is, if any point of it is moved, all other points move in a perfectly definite manner. It is well known that an induction motor at a constant applied voltage is such a system. As the load varies, all the electrical characteristics and the speed vary in only one possible way. It differs in this respect from a shunt-wound direct-current motor in which the field current is a second independent variable, or a second degree of freedom.

Having set the device, the lower knob is moved up and down in the groove. This causes all other members to assume new positions. For any position of the knob readings can be taken of the current, phase angle, torque, slip, output, etc., as in any brake test. Lengths are measured with an ordinary meter scale, and phase displacements may be either measured directly with the sighting goniometor shown in Fig. 9, or computed from the measured projections of vectors, as is explained below.

The Principle of the Indumor. The device is based on the principle of ordinary dividers. Let the two legs on a pair of dividers be denoted $A\,B$ and $B\,C$, with the pivot at B. The length to be measured is AC, and $A\,C$ can be varied at will by opening or closing the dividers, even though the length of the dividers' legs is constant.

Similarly in the Indumor the variable vectors are not represented by the bars themselves, but by the distances between the ends of two bars. The only vector directly represented by a bar is that of applied voltage because it remains constant. Thus, while the Indumor shown in Fig. 1 gives a complete vector diagram of an induction motor, the vectors themselves are represented only by imaginary lines connecting the ends of various bars. By drawing such lines the usual vector diagram is obtained, such as is shown in Figs. 3 and 4.

At the 1918 Midwinter Convention of the Institute the author demonstrated another kinematic device, which imitated the performance of the polyphase series commutator motor (The Secomor, Trans. A. I. E. E., Vol. 37, p. 329). That device was based on the use of bars which directly represented vectors. The lengths were varied by means of slides movable along the bars. The Secomor required a separate setting for each point since it did not have constraining links. The Indumor is a more accurate and automatic device; once set correctly for one point it gives the whole range of operation of the machine, because of properly designed constraining motions.

The Performance Diagram of a Polyphase Induction Motor

It is well known that for certain purposes a polyphase induction motor may be replaced by an equivalent combination of resistances and reactances, as shown in Fig. 2 (see for example the author's "Electric Circuit", Chap. XII). In this diagram one phase only is represented; r_1, x_1, r_2, and x_2, are the primary and the secondary resistances and reactances, the secondary quantities being reduced to the primary circuit, (see for example the author's "Magnetic

Circuit", p. 133). The susceptance b_0 is of such a magnitude that the current I_m passing through it is equal to the actual magnetizing current of the motor. The conductance g_0 causes a joulean loss numerically equal to the primary core loss of the actual machine.

The mechanical load of the actual machine is replaced by an adjustable resistance R; the $I_2^2\,R$ loss

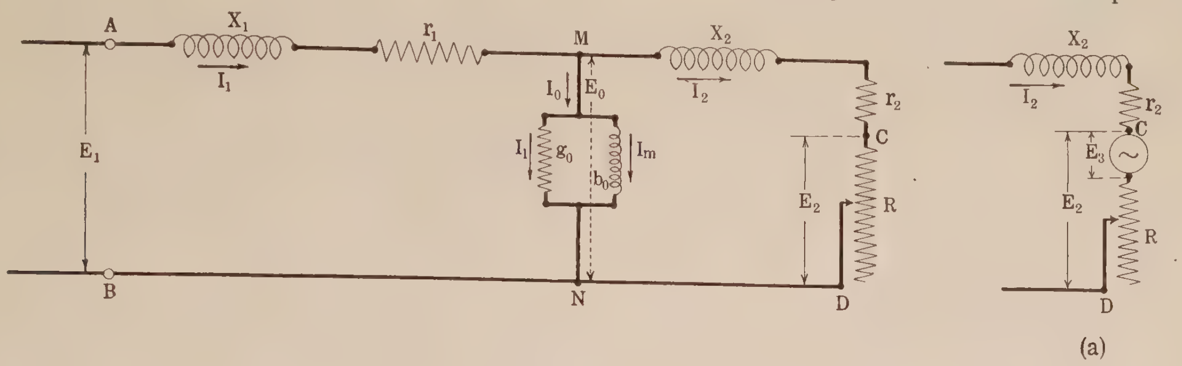

Fig. 2

in this resistance can be made equal to a desired motor load. Strictly speaking, this load, in addition to the useful output, includes the friction, windage, and the secondary core loss. In approximate computations the friction and windage losses are sometimes taken into account in the conductance g_0, but it is better to subtract the mechanical losses from the total output. A still better approximation to the actual conditions could probably be obtained by using three shunted constant conductances, one across the line terminals A B, one across M N, and one between C and D.

A combination of resistances and reactances shown in Fig. 2 gives nearly the same performance curves as the actual motor. Let a certain brake load be applied to the actual motor and let the resistance R of the equivalent combination be so adjusted that the primary current is the same as in the actual motor. Then it will be found that the primary input and the power factor are also the same and that the brake load is equal to $I_2^2\,R$ watts, less the friction and windage.

The slip, being equal to the percentage of secondary loss, can be computed as the ratio of r_2 to $(R + r_2)$, and checks very closely with the actually measured slip. The torque, in synchronous watts, is equal to the input into the secondary circuit and therefore is equal to $I_2^2\,(R + r_2)$. The voltage E_0 between M and N is a measure for the air-gap flux. Thus, all the important characteristics of the motor can be obtained from the equivalent diagram, either by test or by computation.

For the operation as an induction generator, above synchronism, the resistance R should be assumed negative. At synchronism this resistance is infinitely great, and in the transition from motor to generator it jumps from $+\sim$ to $-\sim$. Then it remains negative, decreasing in its absolute value. Another way of representing the generator range is to replace the resistance R by a counter-e. m. f. E_2. At synchronism E_2 must be equal and opposite to the voltage E_0 between M and N in order to reduce the secondary current to zero. As the generator load increases, E_2 must be made greater than E_0, always keeping E_2 in phase with the scondary current, I_2, which is now reversed.

The Vector Diagram. The relationships shown in Fig. 2 are represented vectorially in Fig. 3, which is the familiar transformer diagram at non-inductive load. Beginning with the vector of the air-gap flux, the magnetizing current, I_m, is drawn in phase with it and the core loss component, I_l, in quadrature with it. This gives the total exciting current, I_0, through

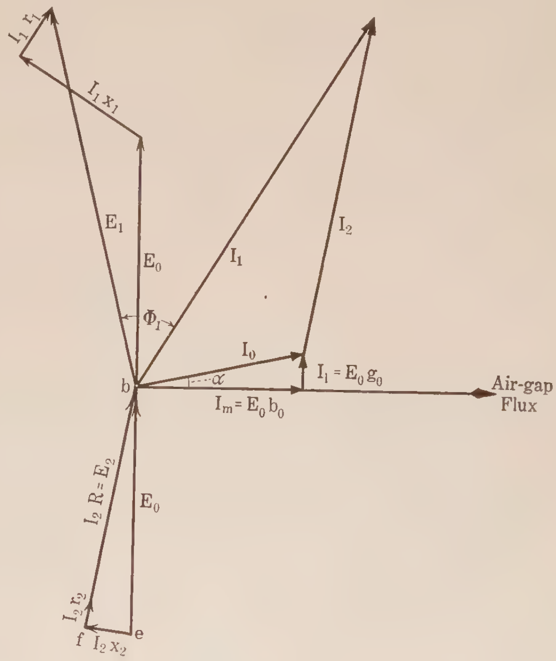

Fig. 3

the shunted admittance between M and N in Fig. 2. This current leads the flux by an angle α.

The voltage E_0 balances the e. m. f. induced by the air-gap flux, and is therefore drawn in leading quadrature with it. The applied voltage consists of E_0 and of the parts $I_1\,r_1$ and $I_1\,x_1$ lost in the primary impedance. The voltage E_0 is used up in the secondary circuit, partly in the impedance of the winding, partly

in the resistance R. The primary current, I_1, is equal to the secondary current, I_2, plus the exciting current I_0.

We thus have the following four fundamental vectorial relationships which must be simultaneously fulfilled in the Indumor:

(a) The geometric sum of E_0, $I_1 r_1$, and $I_1 x_1$, must be equal to the applied voltage E_1.

(b) After subtracting the vector $I_2 x_2$ from E_0, the remainder, $f\,b$, must be in phase with I_2.

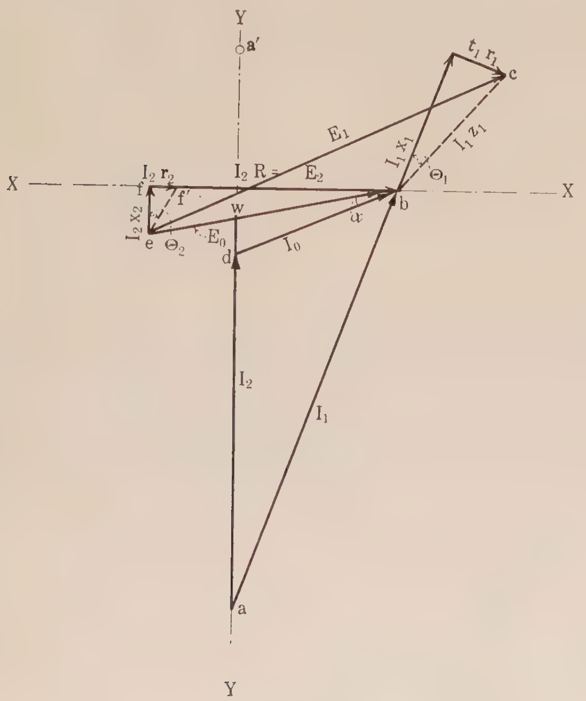

Fig. 4

(c) The geometric sum of I_0 and I_2 must be equal to I_1.

(d) I_0 must be proportional to E_0 and the angle between the two must be constant.

The diagram in Fig. 4 is identical with that shown in Fig. 3, except that some vectors are rearranged in order to simplify the construction of the Indumor. The direction of the secondary current, I_2, is taken as the $Y\,Y$ axis, and the triangle $I_2\,I_0\,I_1$ is drawn accordingly. The triangle $b\,f\,e$ is turned back by ninety degrees, so that E_0 forms the angle α with I_0, instead of $(90° - \alpha)$. Similarly, the quadrilateral built on the primary voltage E_1 is turned back by ninety degrees, and is so placed that E_0 is its common side with the triangle of secondary voltages. The vector $I_2 R = E_2$, which in Fig. 3 is parallel to I_2, is now perpendicular to I_2, and chosen as the direction of the $X\,X$ axis.

In Fig. 4, as well as in the Indumor, all the voltage vectors are turned back by 90 deg. with respect to their true positions in Fig. 3. Or else, the voltages in the Indumor may be said to be in their correct position, but the currents advanced in phase by 90 deg. This must be borne in mind when measuring the phase angle between the primary current and voltage. The operation of the device is not otherwise affected since the currents and the voltages form separate closed figures.

The reason for turning the voltages, or the currents, in the Indumor is that it is mechanically much simpler to make two lengths vary in a constant ratio when they are nearly in line with each other than when they are perpendicular to each other. Neglecting the core loss, the magnetizing current, I_0, in Fig. 3 is at right angles and proportional to E_0. In Fig. 4 I_0 is nearly in phase with E_0, and proportional dividers have been developed which can keep the two vectors in a constant ratio and at a constant angle, when both vectors vary with the load.

Figs. 4 and 8 can be directly compared, the corresponding quantities being denoted by the same letters. Thus, $a\,d$ is the secondary current, $a\,b$ is the primary current and $d\,b$ is the exciting current. The primary impedance drop is $b\,c$, the secondary reactive drop is

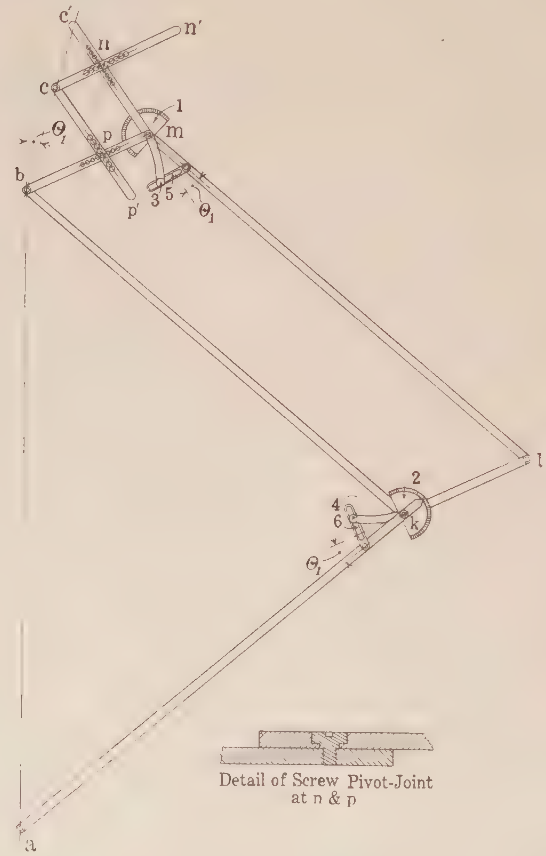

Fig. 5—Proportional Dividers

$e\,f$, the applied voltage is $e\,c$, etc. Since the Indumor is based on the principle of dividers, all the variable vectors are measured between the pivot points of different bars and not along one and the same bar.

The Kinematic Details of the Indumor

Having established the relationship between the vector diagram in Fig. 4 and the linkages in Fig. 8, it

remains to show how the various points are constrained to move along certain paths in order that the four above-mentioned conditions remain fulfilled with any setting of the device.

I. Proportional Dividers for the Primary Impedance Drop

In Fig. 4 the primary current, $I_1 = a\,b$, and the primary impedance drop, $I_1 z_1 = b\,c$, are proportional to each other and their vectors are inclined to each other at a constant angle θ_1, where $\tan\,\theta_1 = z_1/x_1$. Proportional dividers which permit this relationship to be realized are shown in Fig. 5, the corresponding points being also marked *a*, *b*, *c*. The three bars, *a k*, *b k*, and *l m*, are of the same length between the centers. The shorter bars, *k l*, *b m*, and *c′ m*, are also of equal length. By means of protractors 1 and 2, the bars *c′ m* and *k l* are set at the desired angle, θ_1, to the longer bars, and are fastened in that position by means of slotted bars 5 and 6 and head screws 3 and 4. This makes the triangles *b m c′* and *a k b* similar to each other, with their corresponding sides inclined at the angle θ_1 to each other. By opening or closing the dividers, the distance *a b* may now be varied at will, and the distance *b c′* will always remain proportional to it and inclined at the angle θ_1.

The desired length *b c* is different from *b c′*, and point *c* is located by means of the bars *c n′* and *c p′*, by making $b\,p = p\,c$ and $c\,n = c'\,n$. The holes in the upper bars are drilled and counter-sunk; those in the lower bars are drilled and tapped, as shown in the detail sketch. Machine screws are used at points *p* and *n* for fastening the bars together. These screws do not prevent a free rotation of the bars relatively to each other. The triangle *b p c* is similar to *b m c′*, so that *b c* also remains proportional to *a b*.

The bars *a k* and *k b* must be long enough to allow the dividers to be opened for the greatest length *a b* of the vector of primary current for which the Indumor is designed. The shorter bars must allow a setting for the highest percentage of primary impedance drop that will ever be used with the apparatus. To illustrate, let the total length of the bar *e c* (Fig. 8), which represents the primary applied voltage, be 150 cm., and let the highest primary impedance drop, that may ever be encountered under the extreme practical conditions, be say 10 per cent of the applied voltage. Then the length *b c′*, with the dividers fully opened, should be not less than 15 cm. Should a special motor have the primary impedance drop of over 10 per cent, it is only necessary to use a shorter length for the primary terminal voltage. For example, with the vector of primary voltage 75 cm. long, an opening $b\,c' = 15$ cm. corresponds to a primary impedance drop of 20 per cent. Any smaller value of primary impedance drop down to zero, can be obtained by properly setting the point *c*.

When adjusting the dividers it must be remembered that the reactive drop is set in phase with the current, and the ohmic drop in quadrature with it, because in the Indumor the currents are turned by 90 deg. with respect to their true position in Fig. 3. The dividers just described are denoted in Fig. 8 by the same letters.

II. Proportional Dividers for the Secondary Reactive Drop

In the Indumor the secondary reactive drop is taken into account separately from the secondary resistance drop, because the latter is used in measuring the slip and must therefore be represented by a separate length. In the primary circuit the resistance drop and the reactance drop are combined into one vector which is represented by the above described proportional dividers.

The proportional dividers for the secondary circuit are simpler than those for the primary circuit, since their only purpose is to give a length $I_2\,x_2$ proportional to I_2 and in line with it. It will be remembered that in the Indumor the voltages are turned by 90 deg. with respect to their true position in Fig. 3, so that the reactive drop is in phase and not in quadrature with the current.

When the two protractors in Fig. 5 are set on zero, the segments *a b* and *bc* lie on the same straight line, and such a device can be used for the secondary current and reactance drop. The protractors, the slotted bars, and the head screws, can be omitted altogether and the members *a k* and *k l* made of one piece of steel. Similarly, *c′ m* and *m l* can be made of one piece. If now the larger opening, *ab*, of such simplified proportional dividers be applied between points *a* and *d* (Fig. 4), the smaller opening, *bc*, when properly set, will give the length *d w*, equal to the secondary reactive drop. This length is transferred into the position *e f* by means of the parallel double-tongs described under III below.

The secondary proportional dividers are shown in Fig. 8 in their actual position. The secondary current is *a d* and the corresponding reactive drop is *d w*. The three long bars are *a r*, *r w*, and *q d*. The shorter bar is *d u*. Holes are drilled and tapped in some of these bars (Fig. 1) so that *d w* can be made of any desired length. The dividers simply consist of two similar triangles, *a r w* and *d u w*, held together by the bar *q d* so as always to keep the sides *d u* and *a r* of the triangles parallel to each other.

III. Parallel Double-Tongs

The secondary reactive drop *d w* (Fig. 4) obtained by means of the proportional dividers, has to be transferred to the position *e f* at the end of the vector E_1. As the load varies, the distance between *d* and *e* also varies, both in magnitude and in direction, so that it is necessary to connect the points *d*, *w*, and *e*, by means of an adjustable translating device, whose fourth point would give the correct position of point *f*.

Such a device, which might be called "parallel double-

tongs," is shown in Fig. 6 in two positions. The four end-points are lettered d, w, e, and f, to correspond to Fig. 4. The construction of the device is such that $f\,e$ is always equal and parallel to $w\,d$. If $f\,e$ be kept constant and stationary, the tongs will allow only such displacements of the points w and d at which the distance $w\,d$ remains equal and parallel to itself,

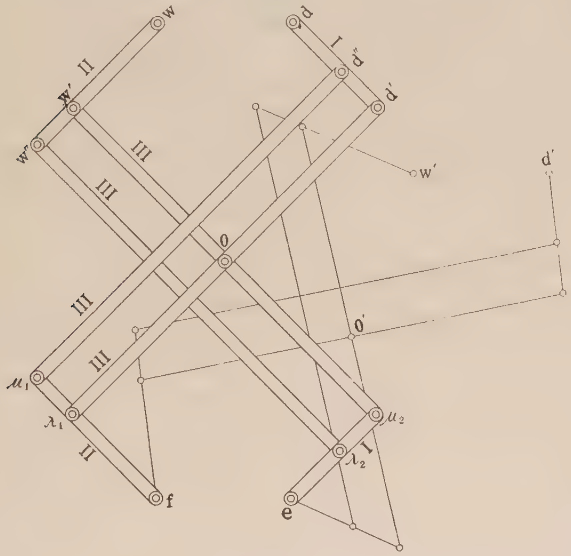

Fig. 6

as shown by the dotted lines. If $f\,e$ be varied in direction and in magnitude, $w\,d$ will vary accordingly.

The device consists of eight pivoted members. There are two short bars of equal length, marked *I*, two equal bars, *II*, of intermediate length, and four long bars, *III*, of equal length. The length $w\,w'$ between the centers must be equal to $d\,d'$, and $w'\,w''$ must be equal to $d'\,d''$. The pivot joint o must be at the center of both long bars which it connects. In other respects the dimensions of the device are arbitrary and depend upon the range of the distances which it is designed to cover. A given distance may also be connected between f and w, instead of between f and e, and an equal and parallel distance is then maintained between e and d.

The parallel double-tongs are shown in Fig. 8 between the points d, w, e, and f, and are marked with the same letters as in Fig. 6; they may also be seen in Fig. 1. In the actual use of the Indumor it has been found convenient to have two pairs of tongs, one for larger distances, when a long bar is used for the applied voltage, and one for shorter distances, for use on overloads and near the starting point of the motor, at a reduced terminal voltage. When the limit of one pair of tongs has been reached they are removed and the other pair is slipped in its place.

The proof of the parallel double-tongs is as follows: Let point o be kept stationary, and let point f occupy any desired position. The vectors $o\,f$ and $o\,d$ are equal and opposite because of the chosen lengths of the links. Similarly the vectors $o\,e$ and $o\,w$ are always equal and opposite; they are also independent of the other half of the device. Thus, the triangles $o\,f\,e$ and $o\,w\,d$ are equal and turned by 180 deg. with respect to each other. Hence, the vectors $f\,e$ and $w\,d$ are equal and parallel.

IV. Proportional Dividers for the Magnetizing Current

In Fig. 4 the magnetizing current, I_0, is drawn at a constant angle α to the voltage E_0. As the load varies, both E_0 and I_0 vary, but their ratio remains constant (neglecting magnetic saturation). As shown in Figs. 2 and 3, the value of the angle α is determined by the relationship

$$\tan \alpha = g_0/b_0 \tag{1}$$

Generalized proportional dividers which permit I_0 and E_0 to vary while satisfying these conditions, are shown in Fig. 7. The lines $b\,d$ and $b\,e$ have the same meaning as in Fig. 4. By turning Fig. 7 by 90 deg. so that point b is on top, it will readily be seen that these proportional dividers are practically identical with those shown in Fig. 5, except for somewhat different proportions. Therefore no new proof is needed for the fact that the triangle $e\,b\,d$ remains similar to itself as the dividers are opened or closed. These dividers are shown in the assembly (Fig. 8) marked with the same letters as in Fig. 7.

The angle which corresponds to θ_1 in Fig. 5 is denoted by β in Fig. 7, and the protractors are set for this angle. It will be seen that angle β is different from the required angle α at b. Since the device is intended to represent angle α, it is necessary to know the

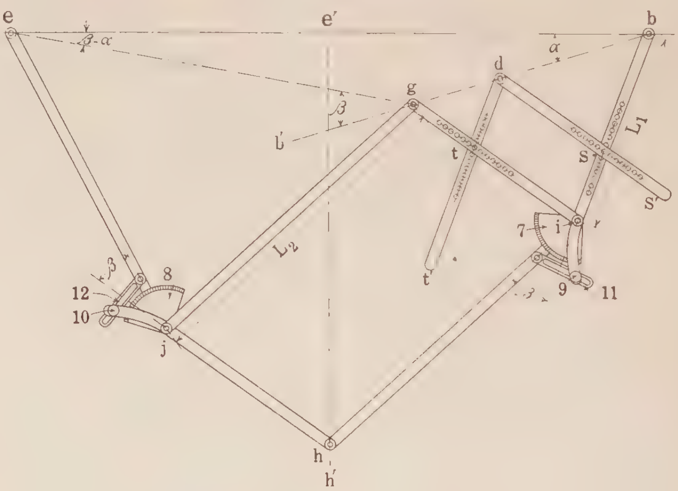

Fig. 7—Proportional Dividers

relationship between α and β. This simple relationship may be obtained either graphically or analytically.

Graphical Solution. On a sheet of paper lay off any reasonable value of $e\,b$ and draw the line $b\,b'$ at the angle α to it. Also draw the perpendicular bisector $e'\,h'$ to $e\,b$. Loosen the head screws 9 and 10, place the ends of the dividers on points e and b, place point h on $e'\,h'$ and point g on $b\,b'$. The readings on

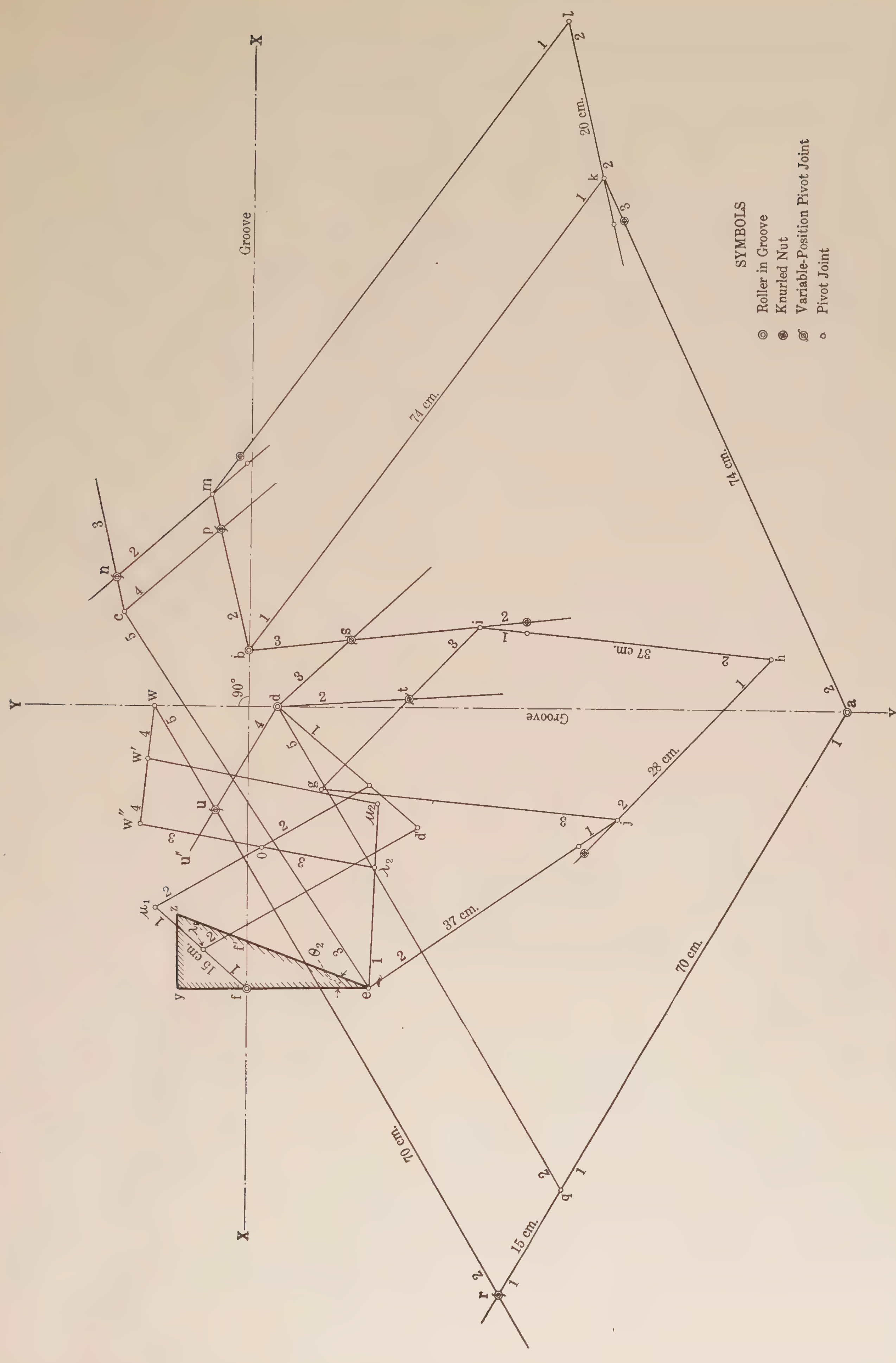

FIG. 8—SINGLE-LINE DIAGRAM OF THE INDUMOR

the two protractors should then be equal and the headscrews should be fastened in this position. As a check, the angle $e\,g\,b'$ should be also equal to β.

Analytical Solution. From the triangle $e\,b\,g$ we have:

$$g\,b/e\,g = \sin(\beta - \alpha)/\sin\alpha \qquad (2)$$

From the similar triangles $e\,g\,j$ and $g\,b\,i$ we have:

$$g\,b/e\,g = L_1/L_2 \qquad (3)$$

Equating the right-hand sides of eqs. (2) and (3), and solving for $\sin(\beta - \alpha)$, we get

$$\sin(\beta - \alpha) = (L_1/L_2)/\sin\alpha \qquad (4)$$

The right-hand side of this equation contains known quantities only, hence the angle $(\beta - \alpha)$ can be found from trigonometric tables and thus β determined. For given dividers, with constant lengths L_1 and L_2, it is convenient to plot once for all a curve of values of β against values of $\tan\alpha$ as abscissas, the values of $\tan\alpha$ being given by eq. (1). It is also possible to mark directly on the protractors values of α opposite the corresponding values of β; then no computations whatever are necessary.

The dimensions of the dividers shown in Fig. 7 are determined by the desired maximum length of the bar $e\,c$ (Fig. 8) which represents the applied voltage E_1. For example, if $e\,c$ is never greater than 120 cm. then the dividers must have a maximum opening between b and e of about the same length, because at no load the voltages E_0 and E_1 are practically equal. The maximum opening $b\,g$ depends upon the largest desired value of magnetizing current. If the maximum length of the vector of primary current at the rated load is to be, say 100 cm., and if the magnetizing current in an extreme case amounts to 40 per cent of that, then the maximum opening $b\,g$ should be about 40 cm. Should the magnetizing current in an unforeseen case amount to over 50 per cent of the full-load current, the scale of primary current for that particular machine may be so chosen that the rated current be equal to say 70 cm. Then a vector of magnetizing current 40 cm. long can be obtained on the dividers, and is over 50 per cent of the rated primary current.

V. Grooves for Keeping the Secondary Current and Secondary Voltage at Right Angles to Each Other

It will be seen in Fig. 4 that the vector of secondary current, I_2, is always perpendicular to the external voltage drop, $I_2\,R$, and to the drop $I_2\,r_2$ in the rotor itself. As the load varies, the magnitudes and the relative positions of the vectors $a\,d$ and $f\,b$ vary, but the vectors remain normal to each other. The author has not succeeded in devising any simple kinematic linkage that would keep two variable vectors at right angles to each other while leaving them otherwise independent of each other. He therefore uses two perpendicular grooves cut in the table or drafting board on which the Indumor is placed. These grooves are marked $X\,X$ and $Y\,Y$ in Fig. 8 and are plainly visible in Fig. 1; their center lines also serve as axes of co-ordinates.

The points b and f (Figs. 4 and 8) are made to move in the groove $X\ X$, and the points a and d in the groove $Y\,Y$. Each point is guided in the groove by a horizontal roller. The required condition of perpendicularity of the two vectors is thus fulfilled without interfering in any other way with the free motion of the four points.

The advantage of the grooves over a linkage is that they are below the surface of the table, and do not add to already numerous bars which must be spaced in different horizontal planes. The disadvantages of the grooves are (a) the device requires a special table and (b) the rollers sometimes bind in the grooves and the bars have to be moved slowly.

VI. The Slip Triangle

In Figs. 4 and 8 the length $f\,b$ is equal to the sum of $I_2\,r_2$ and $I_2\,R$. In order to compute the slip and the output of the motor, it is necessary to measure separately the length $f\,f' = I_2\,r_2$, because the slip

$$s = f\,f'/f\,b = r_2/(R + r_2) \qquad (5)$$

and the output is

$$P_2 = I_2\,E_2 = a\,d\,.\,f'\,b \qquad (6)$$

A separate triangle, *eyz* (Fig. 8), is cut out of ordinary cross-section paper and is used to measure the length $f\,f'$. The angle θ_2 is such that

$$\tan\theta_2 = r_2/x_2 \qquad (7)$$

This triangle is placed with one of its sides in the direction $e\,f$, as shown in Fig. 8, and the length $f\,f'$ is read off directly.

The length $f\,b$ is measured with a meter scale, and the torque, in synchronous watts, is computed from the equation.

$$T = I_2\,(E_2 + I_2\,r_2) = a\,d\,.\,f\,b \qquad (8)$$

The Use of the Indumor

The separate parts of the Indumor are assembled as shown in Figs. 1 and 8; the bar $e\,c$, which represents the constant applied voltage, serves as the closing link. This bar is provided with several holes, so that a voltage scale can be selected which best suits the constants of the motor and the desired region of operation. Actual experience seems to indicate that a long bar $e\,c$ gives better results on light loads and up to the rated current, while shorter lengths are more suitable for representing overload conditions. A selection of the length $e\,c$ determines the voltage scale.

For a three-phase motor, the star or Y voltages and currents can be used, and the results for the input, output and torque later multiplied by three. The line voltage and delta currents can also be used if desired, or the line voltage and the total equivalent single-phase current. In this respect the Indumor can be treated like any vector diagram of a balanced poly-phase circuit.

For a motor of given voltage and rating, the limits of primary current between no-load and a reasonable overload can be readily estimated, and a current scale

can be selected that will permit a free motion of the links within the range of the device.

Knowing the primary resistance and reactance of the machine, the primary proportional dividers (Fig. 5) are set by adjusting the two protractors and the links $c\,n'$ and $c\,p'$, as explained above. Knowing the rotor reactance, the secondary proportional dividers are set accordingly. The slip triangle $e\,y\,z$ is cut out to correspond to the given or assumed rotor resistance.

If the total leakage reactance has been computed from a short-circuit test, the parts to be assigned to x_1 and to x_2 cannot be ascertained, and in ordinary cases the total reactance is divided about equally between the primary and the secondary circuit. To the writer's best knowledge, there is no way of separating the two reactances from the no-load and short-circuit tests alone. The separation can be done if in addition a set of readings is given at some load, preferably at a considerable slip. For a motor which is being newly laid out, the two reactances can be separately estimated by the designer.

From the no-load readings of the machine the proportional dividers shown in Fig. 7 can be set for the proper angle α, as is explained above. It is more nearly correct to allow in the angle α only for the primary core loss, and to subtract the friction and windage losses from the total output computed from eq. (**6**). The magnetizing current at no-load is known, and E_0 is practically equal to E_1. Therefore, by opening the dividers (Fig. 7) to the length of the applied voltage, the position of point d can be ascertained.

The device has now been completely adjusted for a motor of given constants, and can be set for any desired current or slip by moving the knob, a in the slot $Y\,Y$. At any position of the knob, all or some of the following readings can be taken, depending upon the purpose in view:

*Primary current, $a\,b$.
Primary impedance drop, $b\,c$.
Voltage E_0 corresponding to the air-gap flux, $e\,b$.
*Secondary current, $a\,d$.
Secondary reactive drop, $e\,f$.
*Secondary ohmic drop, $f\,f'$.
Secondary impedance drop, $e\,f'$.
Exciting current, $d\,b$.
Magnetizing component of the exciting current, projection of $d\,b$ on $e\,b$.
Core loss component of the exciting current, distance of d from $e\,b$.
*The energy component of the secondary voltage, $f\,b$.
*Angle between I_1 and E_1.
Projections of E_1 on $X\,X$ and $Y\,Y$.
Projections of I_1 on $X\,X$ and $Y\,Y$.
Any other angles between vectors that may be of interest.

For obtaining the usual performance characteristics of the machine, only the quantities marked with an * need be measured. From these quantities the following results can be computed:

Volt-ampere input
Power input
Primary power factor
Slip, eq. (**5**)
Secondary output, eq. (**6**)
Torque, eq. (**8**)
Separate losses
Efficiency.

If the angle α (Fig. 7) has been set to account only for the core loss, then the expressions for the output and the torque include the friction and windage which must be subtracted if net values are desired.

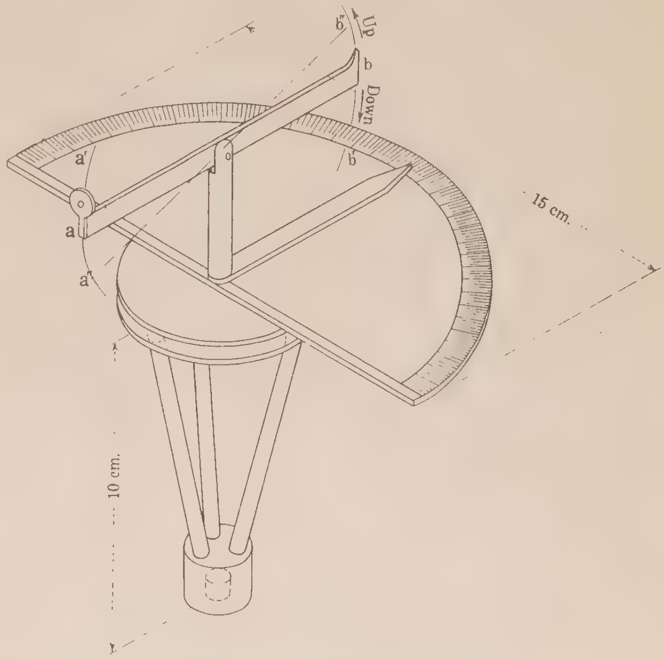

FIG. 9—SIGHTING GONIOMETER

The phase angle between E_1 and I_1 may be measured directly with the sighting goniometer shown in Fig. 9; or else a protractor may be used for determining the angles which each of these vectors forms with one of the axes of coordinates. The phase angle may also be computed from the measured projections of I_1 and E_1 upon the axes $X\,X$ and $Y\,Y$. In any case it must be borne in mind that in the Indumor the angle between these two vectors is complementary to the actual phase angle (compare Figs. 3 and 4).

In order to compute the phase angle from the projections of the vectors it is necessary to assume some positive directions of the axes. Let, for example, in Figs. 4 and 8 the X-direction be positive to the reader's right and the Y-direction be positive upward. Let the projections of the current vector, I_1, on these two axes be i and i' respectively, and those of E_1, *in its true position* (Fig. 3), be e and e'. Let the *actually measured projections* of the E_1 bar in the Indumor be

E_x and E_y. We then have, by advancing E_1 by 90 degrees,

$$\left.\begin{aligned} e &= -E_y \\ e' &= E_x \end{aligned}\right\} \qquad (9)$$

The phase angle ϕ_1 is computed from the familiar formula

$$\tan \phi_1 = \frac{(e'/e) - (i'/i)}{1 + (e'/e)\,(i'/i)} \qquad (10)$$

See for example the author's "Electric Circuit," p. 91, eq. (**144**). The positive and negative signs of the projections must be carefully observed.

The power input can be computed either from the expression $E_1 I_1 \cos \phi_1$, or from the same projections of the vectors, using the formula

$$P_1 = e\,i + e'\,i' \qquad (11)$$

(*ibid.*, eq. **143**).

Indumor in the Generator Range

The operation of an induction motor as a generator may be characterized in the equivalent diagram (Fig. 2) by the phase reversal of the secondary current I_2. Therefore, a continuous transition from motor to generator would be possible in the Indumor if the knob a (Fig. 8) could be pushed upward beyond the groove $X X$. The proportional dividers would not allow such a motion, and therefore the generator range has to be obtained with a below the $X X$ line. This is done by simply considering the actual Indumor as an image of a fictitious one, $X X$ being the reflection line taken as a plane mirror.

Let, in Fig. 4, a point, say a', be selected on the $Y Y$ axis above the $X X$ axis, and let a complete vector diagram of currents and voltages be drawn, following exactly the method used for the point a below the $X X$ axis. The new diagram will give an operating condition of the machine working as a generator. Let now an image of the new diagram be drawn below the $X X$ axis, as if this axis were a plane mirror. Comparing this image diagram with one actually shown in Fig. 4 for the motor range, it will be found that the two differ from each other only in the direction of the vectors of primary and secondary ohmic drop, $I_1 r_1$ and $I_2 r_2$. *The vectors of ohmic drop in the generator "image" diagram are drawn in the opposite directions from those in the motor diagram.*

This relationship gives a simple method of using the Indumor for the generator range. It is only necessary to set the two protractors in Fig. 5 for a negative angle θ_1, and to turn the triangle $e\,y\,z$ (Fig. 8) about $e\,y$ so as to get a point f' to the left of f; this will give a negative slip.

A watch placed horizontally in front of a vertical mirror seems to run counter-clockwise when observed in the mirror. Similarly, a counter-clockwise vector diagram of the generator, when reversed into its image, becomes a clockwise diagram. This fact must be kept in mind in the interpretation of the results when operating the Indumor as an image of the real diagram.

Improvement of Power Factor and Speed Control

In Fig. 2, to the right, a separate sketch (a) shows the equivalent secondary circuit of an induction motor to which an external alternating e. m. f., E_3, has been added. It is well known that the magnitude and the phase angle of this external e. m. f. may be so chosen as either to change the speed of the motor or to improve its power factor, or both. This usually requires either an additional commutator machine or a conversion of the induction motor itself into a polyphase commutator motor.

Fig. 10 shows a corresponding adaptation of the Indumor to a polyphase machine in which an external e. m. f., E_3, has been added to the secondary circuit. The lettering is the same as on the left-hand side of Fig. 8.

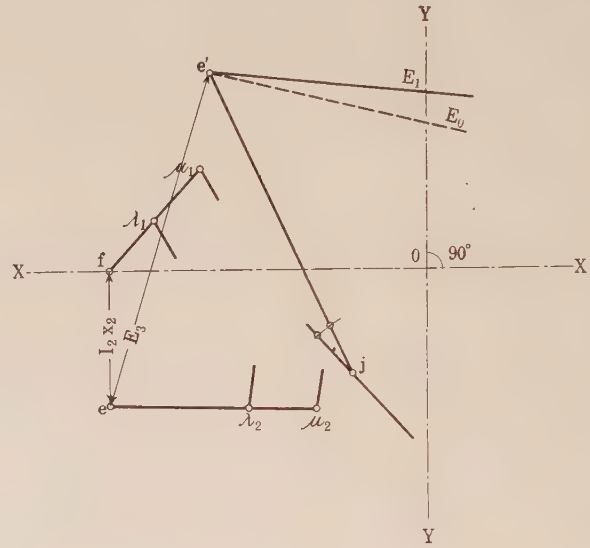

Fig. 10

The added e. m. f., E_3, is represented by the vector ee'. The extremity of the vector E_1 and of the proportional dividers for E_0 are transferred from e to e'. Otherwise the device remains the same. Electrically this means that the voltage E_0 is now balanced by the geometric sum of $I_2\,(R + r_2)$, $I_2\,x_2$, and E_3.

In Fig. 8 the primary current, I_1, lags by a considerable angle behind E_1, when the latter is turned by 90 deg. forward into its real position. In Fig. 10 the bar E_1 has been turned back sufficiently to bring the true vector E_1 almost into phase coincidence with I_1, thus raising the power factor of the machine almost to unity. By taking E_3 in the direction of the $X X$ axis the speed of the induction machine may be varied economically within wide limits.

The additional linkage $e\,e'$ has to be connected to the rest of the device in accordance with the nature of the external e. m. f. E_3. For example, if this e. m. f. is constant in magnitude and forms a constant phase angle with E_1, then $e\,e'$ is simply another bar rigidly connected at a certain angle to the bar E_1. This is the case in a shunt-excited polyphase commutator

motor, E_1 being the voltage applied to the stator and E_3 that applied to the armature brushes. We thus obtain a new kinematic device which may be called the *Shucomor* (an abbreviation of the words "shunt commutator motor").

When a series-wound polyphase commutator motor is connected in series with the rotor windings of an induction motor, as is sometimes the case, the e. m. f., E_3, of this motor is proportional to the secondary current I_2 and the phase angle between the vectors E_3 and I_2 is constant. In this case E_3 can be represented on the Indumor in the same manner as $I_2 x_2$ or $I_1 z_1$. The secondary proportional dividers must be provided with two protractors, like the primary dividers, and $I_2 x_2$ and E_3 combined into one vector whose length is determined by the opening of the dividers which give I_2.

The author hopes to report later more in detail upon these additional possibilities of the Indumor in the study of polyphase commutator motors. As a matter of fact, he started to develop a "Shucomor," and the Indumor came out as a first attempt in this direction.

An interesting computing device has been described by Prof. R. G. Warner in an article entitled "Induction Motor Nomogram," in the A. I. E. E. JOURNAL for October 1921 (Vol. 40, p. 808). The device is based on the simple circle diagram and gives directly the numerical data for performance characteristics of three-phase 60-cycle induction motors. It is hoped that engineers interested in induction motor characteristics will investigate the relative advantages and disadvantages of the Nomogram and the Indumor, and will find out by actual experience the particular field of usefulness of each.

The development of the Indumor has been made possible through the generosity of Mr. August Heckscher of New York City, who gave to Cornell University a special fund the income from which is used for the promotion of research. To him the author's sincere gratitude is due. The device has been in a preliminary stage of development for some years previous to the grants from the Heckscher Foundation, and several of the author's students as well as the mechanicians of the College of Engineering have contributed generously of their ideas. The author wishes to express his appreciation to them all.

A census of all the persons engaged in safety and industrial health work in the public utility industries, as well as all persons engaged in these activities in every other industry and in public safety work, is being taken by the National Safety Council. This is the first time that any attempt has been made to list the thousands of people who are engaged in the safety movement, and the census will therefore be of special interest.

MODULATION PHENOMENA IN RADIO-TELEPHONY

The apparatus now used for transmission in radiotelephony uses three-electrode electron tubes as an essential part of the equipment, with the exception of a few high-power stations which use high-frequency alternators. The development of small and comparatively inexpensive radiotelephone transmitting equipment has been made possible only by the rapid development of the electron tube. The use of radiotelephony is now being rapidly extended, and it is being used for the broadcasting of news of different kinds, such as weather and market reports.

In radiotelephony a wave of a radio frequency such as a million cycles per second is varied in amplitude or "modulated" at audible frequencies such as 1000 cycles per second, in accordance with the wave form of the sound which is being transmitted. The device by which this modulating process is accomplished must respond instantaneously to the variations of the impressed sound wave, and must therefore have negligible inertia, in order that sound may be transmitted without distortion. The electron tube is a device which answers these requirements, since the electron stream will respond instantaneously to variations in the audio-frequency wave. The phenomena occurring in circuits for modulating radio-frequency currents may become very complex, and require careful study. Three principal methods of modulation in electron tube radiotelephone transmitting sets are recognized: First, by variable absorption of the output power of a generator of radio-frequency current, as by inserting a microphone in the antenna circuit; second, by varying at speech frequencies the operating grid voltage of a tube generating radio-frequency current; third, by varying at speech frequencies the input plate voltage of a tube generating radio-frequency current. The third method is often referred to as "plate modulation," and is the method used in commercial and military types of apparatus in the United States. Plate modulation is superior to the other methods in many respects.

Studies have been made at the Bureau of Standards of the phenomena of modulated radio-frequency waves, and the relative advantages of different methods of modulation and different circuits. The apparatus used in radiotelephone transmitting sets employing plate modulation has been analyzed as consisting of four units—the source of direct current, the modulator unit, the generator unit, and the radiator unit. Oscillographic studies have been made. Results of these studies are contained in a publication of the Bureau of Standards just issued, Scientific Paper No. 423, Operation of the Modulator Tube in adiotelephone Sets, by E. S. Purington.

Submarine Cable Telegraphy

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The history of the development of the subject is first outlined, and methods of operation of cables are described. The technical side is introduced with a statement of the various conditions whi h limit operation of cables, and a general method of analysis is developed, based upon an extension of ordinary alternating-current theory. The theory is made use of to analyze the action of cable types and of apparatus which at this time can be regarded as standard. The fundamental theory of the method of analysis, with information on the calculation of transients in electrical circuits, is given in the Appendix.

Historical

THE feasibility of submarine cable telegraphy was suggested by Salva, a Spaniard, as early as 1795. The first actual experiment seems to have been made in 1803. In the period covered by the next forty years, numerous experiments were carried on in different parts of the world for the purpose of demonstrating the possibility of submarine telegraphy. In 1842, Morse transmitted signals over a short section of insulated wire laid in the New York Harbor. The conductor used in this experiment was insulated by covering it with hemp soaked in tar and pitch, and surrounding this with india-rubber. The introduction of gutta-percha as an insulator and the invention of a machine for applying it to wire, gave a decided impetus to the experiments being carried on.

The first commercial attempt to establish electrical communication by submarine cable was in 1850, when a cable was laid between England and France. This cable was broken, however, shortly after communication was established. The cable used in this attempt consisted of a No. 14 copper wire surrounded by gutta-percha to a thickness of one-half inch. The failure of this cable due to its physical weakness led to the design and laying of an improved type between Dover and Calais in 1851. This cable consisted of four No. 16 copper wires, each covered with two layers of gutta-percha to the size of No. 1 gage. These insulated wires were armored with ten No. 1 galvanized iron wires wound spirally. This cable proved to be successful, and in the next few years a number of cables was laid between England and adjacent shores, between Denmark and Sweden, and in the Mediterranean Sea.

The first attempt to lay a cable across the Atlantic was in 1857. This attempt ended in failure when the cable broke in 2000 fathoms of water, at a point about 350 miles west of Valentia, Ireland. As at that time there were no means of recovering a cable in deep water this project was abandoned. In August 1858 the same company, The Atlantic Telegraph Company, completed the laying of a cable. This cable was operated for about three months, when it became interrupted, and no attempt was made to repair it. In the years 1865 and 1866 The Atlantic Telegraph Company laid two new cables. The first cable broke when it was about two-thirds laid. The second cable was then successfully laid, and soon afterward the end of the first cable was picked up with much difficulty and its laying was completed. These cables were operated with no competition until 1869 when the French Atlantic Telegraph Company opened a cable for traffic. With the success of the Atlantic cables established, the growth of submarine cable systems was rapid, until in 1914 there were seventeen cables across the Atlantic between North America and Europe alone, and there was then an aggregate of about 2000 cables in the world, comprising a total length of over 300,000 miles.

The use of gutta-percha as an insulator was adopted at the very inception of submarine cables, and it is still almost universally used for long cables.

The necessity for a protective armor for submarine cables was demonstrated by the failure of the first cable laid in the English Channel. Since that time cables have been provided with a protective armor consisting of a number of iron or steel wires wound spirally around the core. The design of the armor was, of course, changed from time to time as experience demonstrated the desirability of improvement.

Even before the first Atlantic cable was laid it was realized that a very sensitive instrument would be necessary for the successful reception of signals on long cables. Early in 1858 Prof. William Thomson, later Lord Kelvin, perfected an invention that was destined to fill this need. This instrument known as the mirror galvanometer, consisted of a small permanent magnet, with a small mirror fixed to it, suspended by silk fibers and surrounded by a coil of fine wire. By reflecting a light from the small mirror to a screen, a greatly magnified image of the coil movement was obtained. When the 1858 cable was completed, tests showed that signals transmitted with a battery of Daniell cells could be successfully received with the mirror galvanometer. However, when the cable was turned over to the electrician for working, he, believing that a high voltage was best suited for signaling, used a large induction coil, excited by a battery, which yielded a potential estimated at about 2000 volts. Under the strain of this voltage, the insulation began to break down and the signals gradually failed. The mirror galvanometer and Daniell cell battery were then substituted and the cable was successfully worked for a

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short time until the cable finally failed completely. It was the opinion at that time that the high voltage used at first had partly broken down the insulation of the cable, and that the faults thus opened gradually became worse until the insulation failed completely.

The mirror galvanometer, with improvements from time to time, was used universally on long cables for a number of years. In 1867 the siphon recorder was invented. This instrument, which had the advantage of supplying a permanent record of the signals as received, gradually replaced the mirror galvanometer, and in its improved forms it is now largely used in the operation of long cables. Previous to 1871 cables were operated in one direction only, but in that year the duplex system was introduced, which permits the use of the cable for simultaneous transmission in both directions. Other more recent developments of operating apparatus include cable relays, automatic transmission, and cable magnifiers, the latter being introduced about 1908. These developments will be described later.

The maximum operating speed of the 1858 cable before it failed was about 15 letters per minute. When the cable was first opened it required about thirty hours to transmit a message of 150 words from President Buchanan to Queen Victoria. It is interesting to note that at that time the minimum rate on a message from New York to London was £20 for a twenty-word message and £1 for each additional word. From that time until the present, improvements in the cable systems have been such that it is now possible to duplex a good Atlantic cable with an operating speed of 300 letters per minute each way; and the operating economies effected have been such that the maximum cable rate between New York and London is now twenty-five cents per word.

Construction and Laying of Cables

The make-up of a typical deep-sea submarine cable is shown in Fig. 1. The conductor is made up of stranded copper wires, or of copper strips. The actual size of the conductor and of the insulation is determined by the operating characteristics desired.

As previously stated, the insulation generally used in submarine cables is gutta-percha. Gutta-percha is derived from the milky sap of gutta trees. The sap of several different species of trees is suitable for converting into gutta-percha, the quality of the gum from some species being better than that from other species. These trees are found principally in the Malay Islands and Peninsula and in Borneo. The sap is collected from incisions in the bark of the living tree, or by stripping the bark. The gutta is roughly cleansed after its collection, and is coagulated into solid cakes in which form it is imported. In the manufacture of the finished product, the gutta must be further purified and treated before it is suitable for use as insulation.

Another form of insulation, known as "balata" or "gutta-balata," is derived from the sap of a species of trees found in some parts of South America. This has been used in combination with gutta-percha in short telephone cables, and possesses distinct advantages for that purpose. The possibility of using balata for long submarine telegraph cables has been suggested.

Rubber has also been used for insulation of submarine cables, notably for the cable connecting the United States and Alaska. This material is somewhat inferior to gutta-percha for the purpose.

It is necessary to protect the gutta-percha from damage by the iron sheathing by placing some sort of a cushion between them. In modern cables this cushion is generally made up of several layers of jute. Jute consists of the bark fibers of two plants called the "chouch" and "isbund," extensively cultivated in Bengal. The jute is usually tarred or tanned before being used on a cable.

In order to protect the core of the cable from damage after being laid, it is necessary to provide a layer of sheathing or armor wires. These wires also serve to support the cable while being laid, and in case it is later necessary to lift the cable for repairs. The design

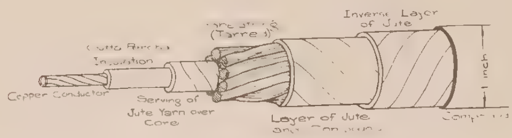

Fig. 1—Typical Section of Cable

depends upon the type of cable—whether deep-sea, intermediate, or shore-end—and in general consists of a number of galvanized iron or steel wires wound spirally. The shore-end types of cables may have two layers of sheathing wires. As a preservative, the sheathing is covered with a layer of jute.

The route for the cable is so far as practicable chosen to avoid deep water, sudden changes in depth, and rocky bottoms. The greatest depth of transatlantic cables is 2.9 statute miles; across the Pacific the cable depth reaches 3.4 miles.

The manufacture of submarine cables has been largely a British industry due to their early interest in and need of a communication system between the various parts of the Empire. The Alaskan Cable is the only long submarine cable that has been manufactured in the United States.

Modern Operation and Apparatus

The following description of apparatus used in regular operation of cables does not aim at being complete. Many devices are developed from time to time for application to cables; some of these are of permanent value and others are of only passing interest. It is the purpose to describe here only some of the important appliances which may be regarded as standard.

Duplex Operation. Generally speaking, a greater output can be obtained by duplex operation of a cable

than by operating in one direction only. Accordingly, cables are ordinarily worked duplex except in cases where it is impossible to maintain a satisfactory duplex balance.

In order to duplex a cable, it is necessary to provide some arrangement by which the receiving instrument is not responsive to outgoing signals, while at the same time it must respond to signals coming from the distant end. There are two common methods of duplexing a communication circuit, both of which involve the use

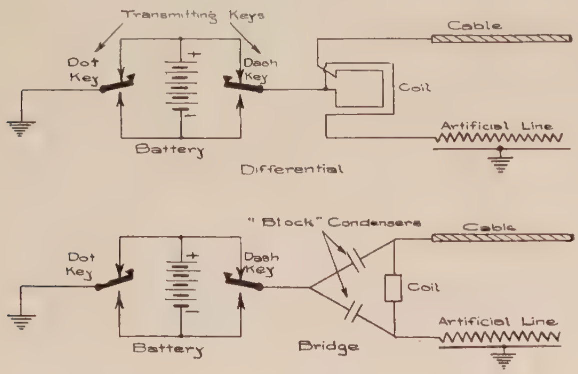

Fig. 2—Duplex Terminal Sets

of an artificial line. These two methods are illustrated in Fig. 2.

In the differential system of duplexing, the coil of the receiving instrument has two separate windings. These are so joined to the cable circuit that in transmitting, the currents in the two windings are equal in magnitude and opposite in direction, thus causing no effect in the local receiving instrument; while currents from the distant station pass through the two coils in the same direction, and cause the receiving instrument to respond.

The bridge method of duplexing employs the principle of the Wheatstone bridge, and is almost universally used for cable working. There is some latitude in the arrangement of the bridge; thus the two condensers

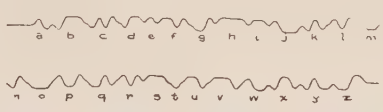

Fig. 3—Letters of the Alphabet Received on Siphon Recorder

may be replaced by resistances or by inductances—the latter arrangement being used by some cable companies. Another plan is to use condensers shunted by high resistances. The use of condensers appears to have advantages for high-speed working of cables, in that it results in better shaped signals.

The Standard Cable Code. The continental Morse code is mostly used for operation of submarine cables. The method of distinguishing dots and dashes is ordinarily different, however, from that in land-line or wireless telegraphy. In land-line or wireless operation the difference between dots and dashes is one of duration, the dash being about three times as long as the dot. In submarine telegraphy the dots and dashes are of the same duration but of different polarity. Dots are formed by applying positive potential to the cable; dashes by applying negative potential. The spacing intervals are obtained by earthing the cable, the zero interval between letters being one unit, and between words usually three units. Fig. 3 shows the alphabet as received on a siphon recorder tape.

Transmitting Apparatus: The Cable Key. For signaling on the cable it is necessary to apply positive, negative or zero potential to the sending end of the cable in various combinations as explained above. In manual signaling a special double-lever key known as the cable key is used. This is shown in theory in Fig. 2. In the normal position of the cable key, both levers are up, thus grounding the cable. When the dot lever is depressed, positive potential is applied to the cable, and when the dash lever is depressed negative potential is applied to the cable.

Fig. 4—Transmitting Tape with Letters of the Alphabet

Manual transmission is employed chiefly in conversations between stations relative to the operation of the circuit.

The Automatic Transmitter. In handling commercial messages a motor-driven automatic transmitter is commonly used in place of manual transmission.

A paper tape is first prepared with perforations corresponding to the message to be transmitted. A sample of this tape with perforations corresponding to the letters of the alphabet is shown in Fig. 4. The tape is passed through the automatic transmitter at the desired speed. The keys shown in Fig. 2 are controlled magnetically from contacts in the transmitter, these contacts in turn being operated in correspondence with the perforations in the tape.

A device known as a perforator is used in preparing the paper tape. The modern perforator has a keyboard similar to an ordinary typewriter and is operated similarly. An electrical solenoid furnishes the power for punching the holes, and the tape is automatically stepped forward.

Receiving Apparatus: The Siphon Recorder. This instrument is generally used in the recording of received cable signals. It is in principle a D'Arsonval galvanometer, with a moving coil suspended between the poles of a strong magnet (Fig. 5). The coil is in the form of a rectangle, a common size being 6 cm. long and 1.8 cm. wide. The coil may be wound to have 500 to

800 ohms resistance. The coil controls the movement of a fine glass siphon pen supplied with ink. The movements of the pen are recorded on a paper tape drawn at uniform speed beneath the siphon. The coil and siphon are separately mounted, and are connected by

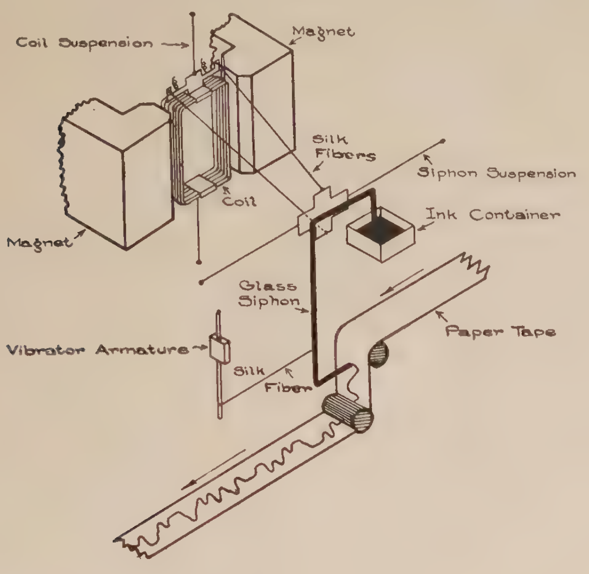

Fig. 5—Moving Elements of Siphon Recorder

silk fibers arranged to magnify the motion of the coil. To reduce friction between the siphon and the tape, the siphon is vibrated vertically with respect to the tape. This is accomplished by an electric buzzer arrangement, the armature of which is connected to the siphon by a silk fiber.

The coil and the siphon are suspended by fine wires the tension of which may be varied, thus permitting the natural period of the moving system to be adjusted according to the speed of the incoming signals. For the recording of well-shaped, undistorted signals, it is necessary that the coil return to its zero position quickly when the current flow ceases, and it is also necessary that the coil shall not swing beyond its zero position. It is sometimes necessary to provide damping for the moving system, which may be accomplished electromagnetically by having the coil shunted with a high resistance, or may be secured by having a small aluminum vane attached to the coil and moving in oil.

A siphon recorder gives a readable signal when actuated by from 30 to 100 microamperes, (0.000030 to 0.000100 ampere).

Magnifiers. In order to increase the speed of a cable above a point where satisfactory operation can be obtained with a siphon recorder alone, it is necessary to magnify the weakened signals before passing them through the recorder. With the magnifiers described below, good signals may be obtained when the current in the magnifier coil is as small as from two to fifteen microamperes.

The Heurtley Magnifier. One type of magnifier extensively used was patented by E. S. Heurtley. This magnifier (Fig. 6) is similar in principle to a siphon recorder, with the coil controlling the movement of two fine platinum wires. Associated with the two moving wires are two similar fixed platinum wires, the relative positions of which are indicated in the figure. The platinum wires are heated by battery current. When the relative positions of the wires are changed by movement of the coil from its mid-position, the mutual heating effect between the fixed and moving wires is altered. Thus the temperature and hence the resistance of the wires in one arm of the bridge are increased, the values being decreased in another arm. The resulting bridge unbalance causes a current to flow in the siphon recorder.

The Selenium Magnifier. The selenium magnifier, also used in operation of long cables, was developed by T. B. Dixon, K. C. Cox and others. It is also of the moving-coil type, the coil carrying a small mirror. This mirror reflects a strong beam of light on to a bank of two or four selenium cells, which form either two or four arms of a Wheatstone bridge. Battery is connected across one diagonal of the bridge and the ordinary siphon recorder is placed in the other diagonal. The electrical resistance of selenium cells varies inversely with the strength of light to which they are subjected. When a movement of the magnifier coil causes a movement of the light beam on the selenium cells, the bridge is unbalanced and current flows in the siphon recorder.

The Vacuum-Tube Magnifier. Some experimental work has been done on the application of vacuum-tube magnifiers to cable operation and fair results have been obtained. There has not been a large incentive to

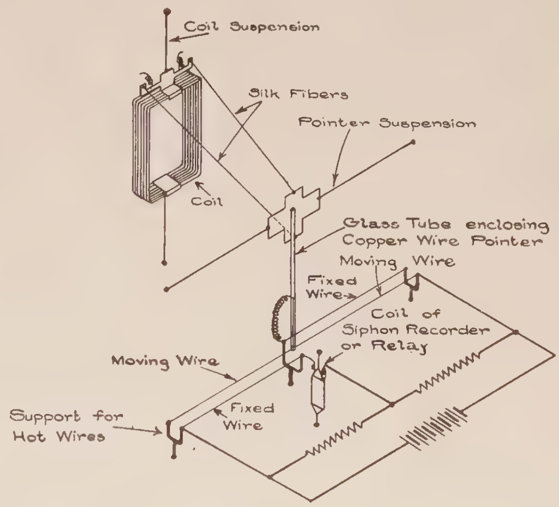

Fig. 6—Heurtley Magnifier

developing the vacuum-tube magnifier, because of the condition that other fairly satisfactory magnifiers were already available.

Cable Relays. In some cases it is desirable to repeat signals automatically from one section of cable into

another rather than to record them. It is essential that a cable relay used for this purpose shall have a reliable form of electrical contact. All of the standard types of cable relays employ the principle of the D'Arsonval moving-coil galvanometer, and differ only in the method of making contact. A relay may be used with or without a magnifier in circuit, the relay alone being approximately as sensitive as a siphon recorder.

The Brown drum relay has an iridium-pointed platinum wire, the movement of which is controlled by the relay coil, making contact on the insulated silver rings of a rotating drum. With very little pressure the iridium point makes good contact on the moving silver, and the friction resisting the lateral movement of the contact point is small.

In the Muirhead gold wire relay, the coil controls the movement of a gold wire between two platinum contacts. The gold wire is maintained in rapid vibration by an electric buzzer arrangement, for the purpose of securing better contact.

The Bruce relay contact scheme consists of a fine nickel wire controlled by the moving coil, which makes contact in drops of mercury. The nickel wire is rapidly vibrated vertically with respect to the contact surfaces, thus reducing frictional resistance to its lateral motion.

Shaping of Signals. In addition to apparatus previously mentioned, various auxiliary devices are used in order to shape properly the received signals. Such devices comprise coils known as "magnetic shunts" connected in parallel with receiving equipment, condensers in series with receiving equipment, and various special pieces of apparatus. The use of condensers in the bridge arms (Fig. 2) has a very beneficial effect in improving signal shape. The action of these devices will be taken up later. A complete cable circuit is shown in Fig. 10.

In relay reception of signals, it is necessary to pay attention to the tendency of signals to have a slowly wandering zero position. This effect is caused by the block condensers, and if conditions are otherwise correct it may be eliminated by providing the condensers with high-resistance shunts. The latter expedient, however, is not always considered desirable, and in order to correct a slowly wandering zero in relay reception, there have been various ingenious devices developed which need not be described here.

Cable Printers. A very promising development, likely soon to be in commercial form, is the application of printing systems of reception to long cables. The code that can be used in a printing system has fewer characters per word than the ordinary cable code. In addition to the economies made possible by the use of a shorter code, a cable printer is also likely to effect economies in operation due to the fact that fewer attendants will be required than with the present system.

Eastern Telegraph Company's System. The Eastern Telegraph Company has recently patented a system of operation which is quite different from conventional methods of operation. In this system the original—not the modified—continental code is used. The original continental code would ordinarily be less efficient, but some special apparatus has been developed which largely overcomes this objection. The system has the advantage that it can be operated through relays directly to the land lines, using land-line apparatus already standard.

Limiting Conditions of Cable Operation

The object of submarine cable engineering is to provide cables which give greatest operating speed and greatest reliability at least cost, and to develop operating methods which make use of the cable to its utmost capacity. A further object of almost equal importance is to reduce operating expenses.

The cost, in place, of a single section of submarine cable of modern type 2000 miles in length is in the neighborhood of $4,000,000. This represents an annual charge of approximately $400,000, to cover interest, maintenance, etc., of the cable itself. The cost of efficiently operating such a section of cable is likely to be in the neighborhood of $200,000 per year, for salaries of men and apparatus directly used in handling traffic. From these figures it is evident that considerable engineering can be justified to obtain highest working efficiency of cables.

A cable of modern type 2000 miles long would have approximately 3000 ohms resistance and 800 microfarads electrostatic capacity to ground. The operating speed, or the message capacity, of a cable is directly limited by its resistance and capacity. The resistance and capacity can be reduced in designing a cable only by increasing the size of the cable, which proportionately increases its cost.

Besides the constants of the cable itself, there are other factors which act in different cases to control the ultimate speed of a cable. These factors are enumerated below.

1. *Sensitiveness of Receiving Apparatus.* If a cable is worked at a very low speed, it is possible to transmit sufficient energy through it to operate receiving apparatus which is substantial in construction. When the speed is increased the current transmitted through the cable falls off very rapidly, due to the effect of resistance and capacity. The decrease in received current is met as far as practicable by providing receiving apparatus of increased sensitiveness. If the apparatus is not sufficiently sensitive, the operating speed may be definitely limited thereby—in fact it may be said that previous to ten or fifteen years ago, cable speeds were definitely limited by the lack of sensitiveness of available receiving equipment. Since that time, however, cable magnifiers, to which reference was previously made, have been developed to a point where they are practically as sensitive as is desired. While there is still some room for improvement the sensitiveness of

available magnifiers is such that other factors, given below, now largely limit the speed.

2. *Duplex Balance.* Due to small but unavoidable errors in the artificial line necessary for duplex working, there is likely to be some degree of off-balance, causing extra currents in receiving apparatus which act to limit the speed. The duplex balance is probably the most important limitation upon speeds of the majority of cables, for even if the cable is once correctly balanced, the balance is subject to change due to variations caused by small temperature changes of the ocean. Much can be accomplished by careful engineering in decreasing balance troubles. Some of the possibilities of improvement will be taken up in detail later.

3. *Extraneous Current.* Although not generally known, it is a fact that ocean cables are subject to continuous interference from extraneous currents in much the same way that interference is caused to wireless telegraph operation. The extraneous currents which affect ocean cables are probably partly caused by electric railway systems. Possibly part may be due to the operation of wireless systems. The greater part of the extraneous currents are, however, of unknown origin, and are doubtless akin to the "static" so familiar to wireless operators. The current is very irregular in nature and may be considered to contain currents of all frequencies. In practise it is usually found that extraneous currents are smaller in magnitude than the currents present due to slight errors in the duplex balance, although in some cases the extraneous currents are the larger. If the balance is improved extraneous currents become of increased importance, and they must be regarded as forming an ultimate limit to further increase in speed of a cable.

It is customary to make use of an earth connection for cable working which is extended several miles from shore. By this means disturbances from electric railway systems are largely reduced. Currents from other sources may be somewhat decreased by the same expedient, although they can not be eliminated. Extraneous currents may be picked up at any point along the cable and conveyed into the receiving apparatus, although the greater part is introduced by slight unsteadiness of the sea-earth connection, of amounts ranging from 0.0001 to 0.005 volt or higher.

4. *Sending Voltage.* The amount of voltage used for operating the cable has a bearing upon the operating speed. A short section of gutta-percha cable is capable of withstanding as much as 40,000 volts before being punctured. A long cable, however, is likely to contain weak spots, which may be punctured at a much lower voltage. In fact, there are instances where cables have been broken down by a few hundred volts. The cost of making repairs to a cable which has been damaged is large, and it is therefore customary to keep operating voltages down to a conservative value.

A potential of 50 volts is commonly used for operation. Due to the effect of the sending condenser, the strain caused to the cable is somewhat increased, so that the insulation near the end is subject to a maximum strain of about 75 volts. In the center of the cable the maximum strain on insulation is very much lower.

5. *Magnetic Storms.* Fortunately, magnetic storms occur only at comparatively wide intervals, otherwise cable engineering might have developed along entirely different lines. Magnetic storms are ordinarily, if not always caused by conditions on the sun. Slight effects from this source are fairly common, but severe magnetic storms occur only rarely, sometimes years apart. Whenever a severe storm occurs, there are displays of the aurora borealis in the sky, the compass needle is affected, and voltages ranging up to several hundred volts are induced in cables. The voltages alternate from one direction to the other in an irregular manner and at a low speed. The period of the reversal may be a few seconds or it may be as long as a half hour. A severe storm may make cable operation impossible for several hours and its effect may not entirely disappear for three or four days.

The Arrival Curve

If a direct-current voltage is suddenly impressed upon a cable grounded at the far end, a current flows into the cable according to the upper curves of Fig. 7. At the distant end of the cable, the current builds up according to the middle curve. The shape of this curve was originally worked out by Lord Kelvin in 1855. The strength of current received through the cable finally reaches a value many times stronger than that necessary to operate the usual receiving apparatus. The rate of increase of current is so slow, extending as it does over several seconds, that rapid signaling with a simple cable circuit is impossible. The various condensers and magnetic shunts introduced in the cable circuit for shaping signals act to remove the greater part of the received current, while retaining the sharp initial rise of current. The result is that the current in the receiving coil is approximately of the shape of the lower curve.

A curve such as one of the lower curves of Fig. 7, which shows the current received over a cable due to a suddenly impressed voltage, is known as an "arrival curve." Any combination of signals may be built up by algebraically adding a succession of arrival curves, in the manner illustrated in Fig. 8.

In studying cable operation, it is convenient to think in terms of the arrival curve. It is essential that the arrival curve be of proper shape, within certain limits, in order that all signal combinations may be legible. In Fig. 9 are shown various shapes of arrival curves, and also the shapes of the first three letters of the alphabet, built up by proper addition of a succession of arrival curves of the shapes given.

The Dot Frequency. By *dot frequency* is meant the normal frequency of operation when a succession of reversals is sent without spaces between them. Thus,

the letter *a*, consisting of one dot above, and an equal deflection below the zero line, is considered to be one cycle. The letter *c* is considered to be two cycles. In Fig. 9, the base line of each arrival curve is shown divided into equal spaces. Each of these spaces represents the length of one dot, that is, one-half cycle.

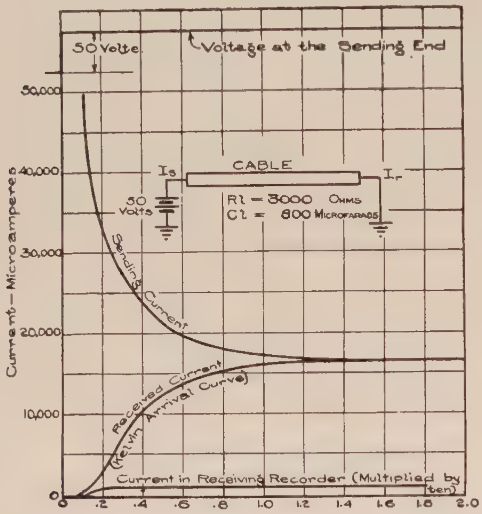

Fig. 7—Sending and Received Current over Cable

A cable such as that previously referred to, with 3000 ohms and 800 microfarads, could be commercially worked at a speed of 54 words per minute, or 324 letters per minute, under favorable conditions. By analyzing the standard cable code, it is found that this is equivalent to an average dot frequency of approximately ten cycles per second.

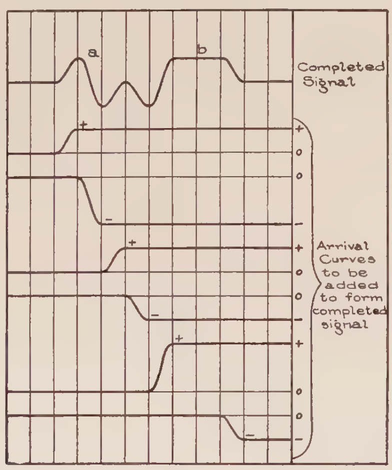

Fig. 8—Addition of Arrival Curves to Form Completed Signals

Theory of Cable Operation

The theory to follow is based upon the use of ordinary alternating-current theory. *A knowledge of the behavior of the cable and its associated apparatus under the influence of a sine wave of current throughout the proper range of frequencies, is sufficient to enable the shape of received signals to be predicted.* The action of any equipment may be determined by investigating its behavior through a range of frequencies. The frequencies which must be considered in cable investigations are those from zero frequency to a frequency two or three times the so-called "dot frequency" of operation, as explained later.

The fundamental theory of this method of analysis is developed in the Appendix. It is shown there that in general any transient curve may be considered to be composed of the sum of an infinite number of pure sine waves, of frequencies varying from zero to infinity. Each of these sine waves is attenuated in the cable circuit in accordance with well-known laws. Even the mechanical motion of receiving coils may be approximately or exactly solved by applying methods such as are used in solving alternating-current circuits.

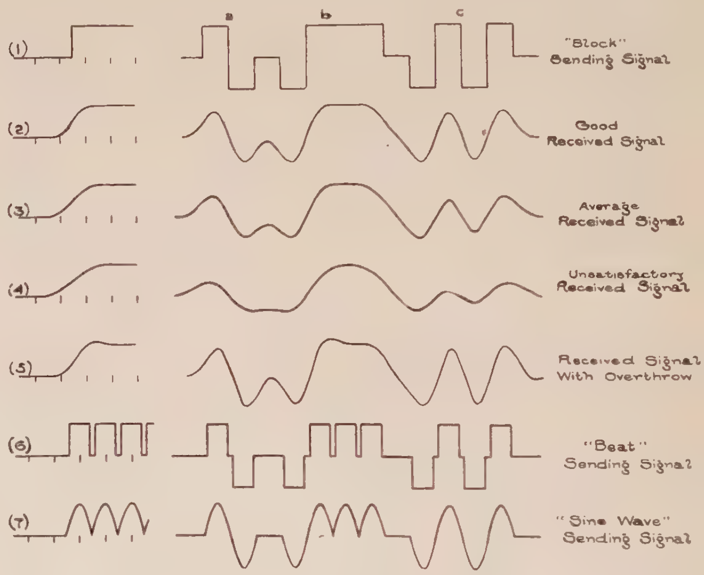

Fig. 9—Types of Arrival Curves

While this method of analysis is of quite general application, it will be illustrated by applying it to the cable of standard present-day type previously referred to, and to simple apparatus used for operation.

The Frequency Characteristic. This term is used to designate a pair of curves which show how sine wave currents are changed in magnitude and in time lead or lag, by the cable circuit or by a part of the circuit, at various frequencies.

Notation.

E = battery voltage.

E_s = sending voltage as modified by type of signal used.

R = cable resistance per mile (inductance and leakage of cable are ignored).

C = cable capacity per mile.

l = cable length in miles.

f = frequency in cycles per second.

F = dot frequency in cycles per second.

Z_0 = surge impedance of cable $= \sqrt{\dfrac{R}{j\,2\,\pi\,f\,C}}$ [1]

P = complex attentuation constant

$= \sqrt{j\,2\,\pi\,f\,R\,C}$ [1]

I_s = current at sending end of cable.

I_r = current at receiving end of cable.

Z_s = impedance offered to outgoing current by apparatus at sending end.

Z_r = impedance of complete receiving system.

D = deflection of receiving instrument. The maximum deflection (neglecting a momentary overthrow) is taken as unity, the deflection at any frequency being expressed as a fraction of the maximum.

M = magnification of complete receiving set at any frequency = ratio D/I_r.

Solution with Single-Frequency Alternating Current. A standard expression for current received through a cable is the following:

$$I_r = \frac{E_s\,Z_0}{(Z_0^2 + Z_r\,Z_s)\sinh P\,l + (Z_0\,Z_r + Z_0\,Z_s)\cosh P\,l} \qquad (1)$$

This may readily be put into the form

$$D = \frac{E_s}{Z_0 + Z_s}\cdot\epsilon^{-Pl}\cdot\frac{2\,Z_0\,M}{Z_0 + Z_r}\cdot\frac{1}{1 - \dfrac{(Z_0 - Z_r)\,(Z_0 - Z_s)}{(Z_0 + Z_r)\,(Z_0 + Z_s)}\,\epsilon^{-2\,Pl}} \qquad (2)$$

The first term of the right-hand member of equation (2) gives the current flowing into the cable, as modified by apparatus at the sending end. The second term shows how the current is modified by the cable itself, and the third term shows how the current is modified by the receiving apparatus as a whole. The fourth term takes into account multiple reflections between the ends of the cable. The latter term may for all practical purposes be considered equal to unity, and may be ignored, as it has no effect except at speeds far below the usual signaling speed.

Analyses of Arrival Curves. If a voltage is impressed at the sending end of a shape corresponding to curve 1, Fig. 9, and the cable circuit as a whole, including apparatus, attenuates all frequencies equally, the wave as received at the distant end will be of exactly the same shape. Under these conditions, all signals would be reproduced at the receiving end exactly as they were sent.

If the characteristics of the cable circuit are such that the higher frequencies are lost in transmission, then the tendency is to round off the corners of the wave in a definite manner, so that a more or less rounded signal is the result. Such rounding-off is not objectionable providing it is not carried too far. It becomes then of the utmost importance to determine just what frequencies it is necessary to transmit through the cable in order to obtain a received signal that is sufficiently legible. Since the higher frequencies are most difficult to transmit through the cable, it will be obvious that the ideal shape of arrival curve is one which, while giving good signals, requires the transmission of the smallest possible amount of the higher frequencies. In order to determine what frequencies it is necessary to transmit, a theoretical analysis was made of a large number of possible arrival curves, using methods given in the Appendix, and tests were also made of working cable circuits.

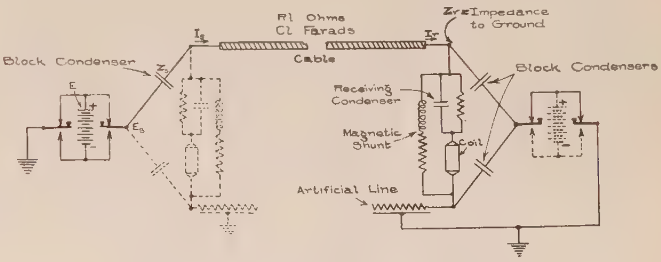

Fig. 10—Complete Cable Circuit

In order to obtain a received signal which, while somewhat rounded, may be regarded as perfect in shape, it is found necessary to transmit frequencies through a cable up to approximately 2.4 times the dot frequency. Fortunately, however, a received signal of such quality is not necessary for commercial operation, since the rece ving operator becomes so familiar with signals that he is able to read signals which are moderately distorted. It has been found that for recorder reception, with or without a magnifier in circuit, it is necessary to transmit frequencies only up to about 1.5 times the dot frequency in order to obtain a signal which is suitable for traffic.

For relay reception a somewhat better defined signal is necessary, and it is necessary to transmit frequencies up to about 1.65 times the dot frequency. Relay reception is facilitated by permitting a small overthrow of the arrival curve. It can be shown that such an arrival curve can be built up with smaller amounts of the higher frequencies.

Examples of signals which have been chosen to represent the approximate limits of good transmission, for recorder and relay reception respectively, are shown

1. In the general case, with inductance L and leakage G present, these become,

$$Z_0 = \sqrt{\frac{R + j\,2\,\pi\,f\,L}{G + j\,2\,\pi\,f\,C}}$$

$$P = \sqrt{(R + j\,2\,\pi\,f\,L)\,(G + j\,2\,\pi\,f\,C)}$$

opposite curves 3 and 5 of Fig. 9.[2] These arrival curves are redrawn to a larger scale in Fig. 11.

In Fig. 12 are shown the frequency characteristics corresponding to the above arrival curves. These

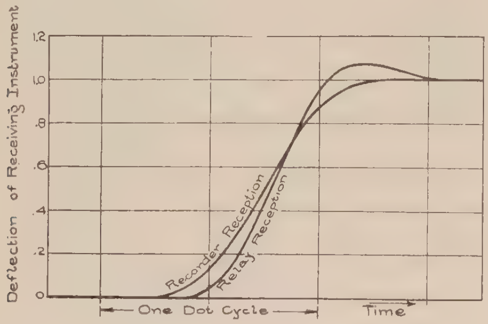

Fig. 11—Ideal Arrival Curves

characteristics show the approximate deflection and time lag which the receiving instrument must have at any frequency, when a sine wave of voltage is impressed at the sending transmitter. The portion shown solid is considered to represent the *working frequency,* which is of importance in determining the shape of the received arrival curve. The precise shape of the portion shown dotted is unimportant as regards transmission through the cable, both because the energy transmitted through the cable is small at these frequencies, and because due to the nature of the equations of this theory as given

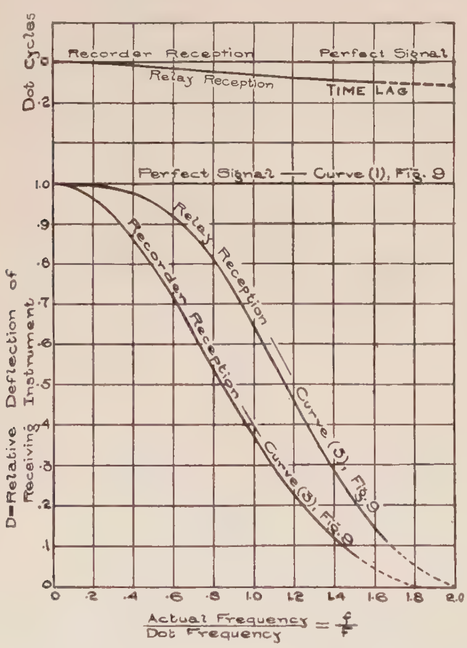

Fig. 12—Ideal Frequency Characteristics of Complete Cable Circuit

in the Appendix, the higher frequencies are of less importance.

It will be recognized that there may be some dif-

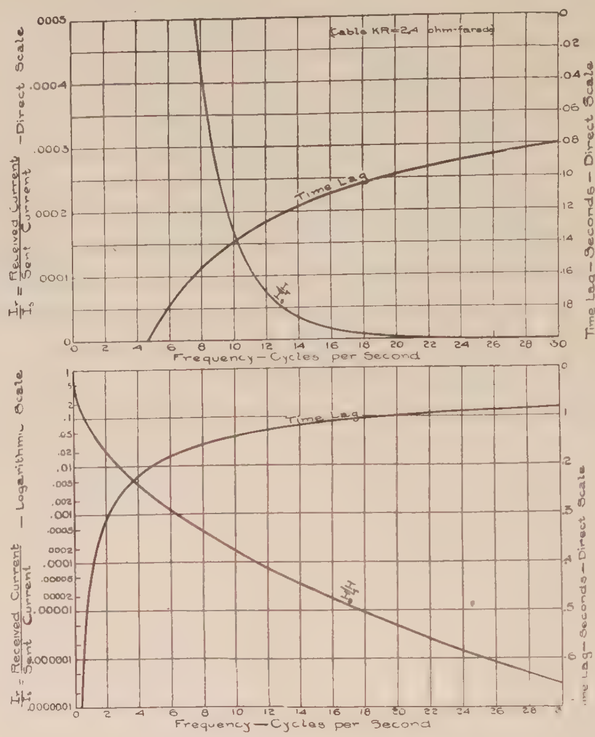

Fig. 13—Frequency Characteristics of Cable

ference of opinion as to when the received signal is legible. For this reason there is some variation in the frequency limits required for reception by different cable operators. The limits given, however, may be

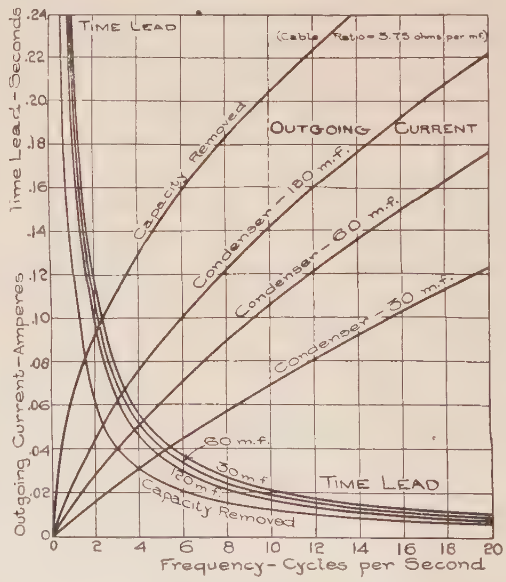

Fig. 14—Frequency Characteristics of Sending Apparatus

taken to represent average values, and are of the highest importance in studying cable problems.

Frequency Characteristic of Cable. The frequency

2. The following table gives the range of frequencies contained in each curve of Fig. 9:

Curve 1, 6 and 7—zero to infinity
" 2—zero to 1.9 times the dot frequency
" 3— " " 1.5 " " " "
" 4— " " 1.1 " " " "
" 5— " " 1.65 " " " "

characteristic given in the preceding section was the characteristic of the entire cable circuit, from transmitter to recorder, necessary for proper reception. It is now the purpose to determine the separate frequency characteristics of different parts of the system.

The frequency characteristic of the cable itself is shown in Fig. 13. This characteristic applies to the cable referred to previously. It is shown plotted both to a logarithmic and to a direct scale. The characteristic was determined by calculating real and imaginary values of the second term of the right-hand member of equation (**2**).

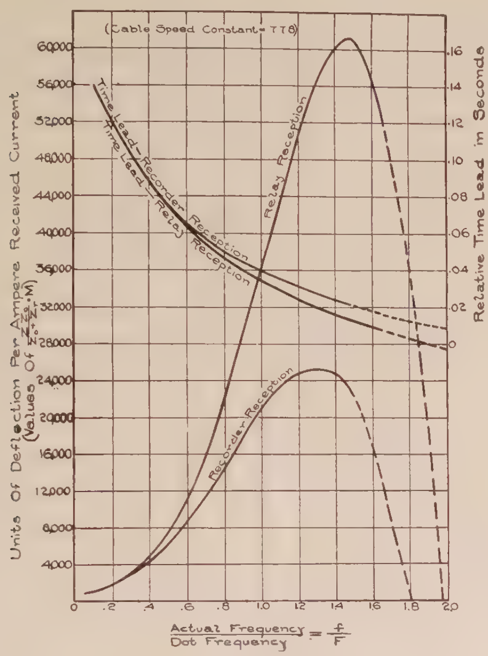

FIG. 15—FREQUENCY CHARACTERISTICS OF COMPLETE RECEIVING SET

Frequency Characteristics of Sending Apparatus. In Fig. 14 are shown frequency characteristics of the current entering the cable, for three different sizes of the condensers at the sending end, and also with the condenser removed. The values in this figure were obtained from the first term of the right-hand member of equation (**2**), the sending voltage being taken at fifty volts.

This figure clearly shows the beneficial effect of the sending condenser in decreasing currents of the lower frequencies. The condenser also reduces, in a less degree, the amount of energy flowing into the cable at higher frequencies—an effect which in itself is undesirable, but which can be compensated for by increasing the sending voltage or the sensitiveness of receiving apparatus.

Frequency Characteristics of Receiving Apparatus. By combining the frequency characteristics shown in Figs. 13 and 14,[3] the frequency characteristic of the current at the receiving end of the cable may be obtained. Now since Fig. 12 shows the frequency characteristics of the cable circuit as a whole, necessary to produce properly shaped signals for reception, it is possible by combining these characteristics with the characteristics referred to above, to obtain characteristics which show the necessary behavior of the receiving set. Such characteristics are shown in Fig. 15.

The characteristics of the receiving set show that this apparatus must be comparatively insensitive to low-frequency currents. It must have its highest sensitivity to currents about 1.3 times the dot frequency for recorder reception, or about 1.45 times the dot frequency for relay reception. The working ranges of frequency, which are important in determining shapes of received signals, are shown as before by solid lines. There are decided advantages from the standpoint of freedom from interference, in having the receiving apparatus insensitive to frequencies higher than the working frequencies.

It is interesting to consider the manner in which the receiving set is made to have characteristics of the shape given. The receiving set is composed of a number of condensers and shunts as shown in Fig. 10. While it is entirely practicable to calculate the frequency characteristic of each part of the circuit, it appears unnecessary to give such calculations here, and a statement will simply be made of the general characteristics of different parts of the receiving set.

The receiving characteristics in Fig. 15 are in fact plots of the quantity

$$\frac{2\,Z_0\,M}{Z_0 + Z_r}$$

taken from equation (**2**). In this quantity, the factor

$$\frac{2\,Z_0}{Z_0 + Z_r}$$

does not greatly vary from unity. The characteristic may therefore be considered to be an approximate plot of the quantity M, which is the ratio of the deflection of the receiving instrument to the current in amperes at the receiving end of the cable. The largest deflection shown is 61,000 units per ampere—that is, full deflection is obtained with 1/61000 ampere = 16 microamperes.

The magnetic shunt, Fig. 10, tends to cause a characteristic which rises with frequency, that is, the shunt tends to absorb currents of lower frequencies, while throwing the higher frequencies into the receiving coil. The condenser in series with the coil has an effect similar to that of the magnetic shunt, and tends to increase further the slope of the characteristic of the complete set.

The block condensers at the receiving end are in effect shunted around the receiving coil and tend to shunt or absorb currents of the higher frequencies. An additional condenser is sometimes placed in shunt with the receiving coil. The values should be such that these condensers mainly absorb only currents

3. The 60 μf. curve of Fig. 14 was used.

above the working frequencies. Such a characteristic may be very beneficial, as it reduces balance troubles and interference from outside sources. The condensers

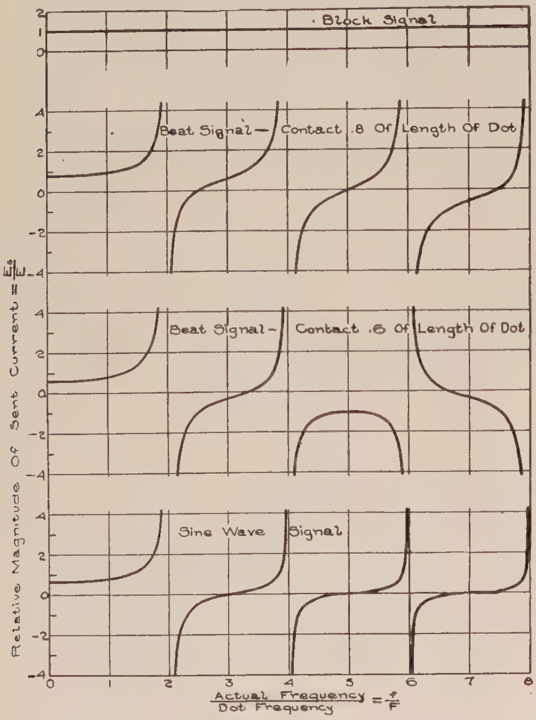

Fig. 16—Frequency Characteristics of Sending Signals

may be semi-resonant with the magnetic shunt, at a frequency between 1.2 and 1.5 times the dot frequency.

The recording coil has inertia which tends to make it relatively insensitive to the higher frequencies. The

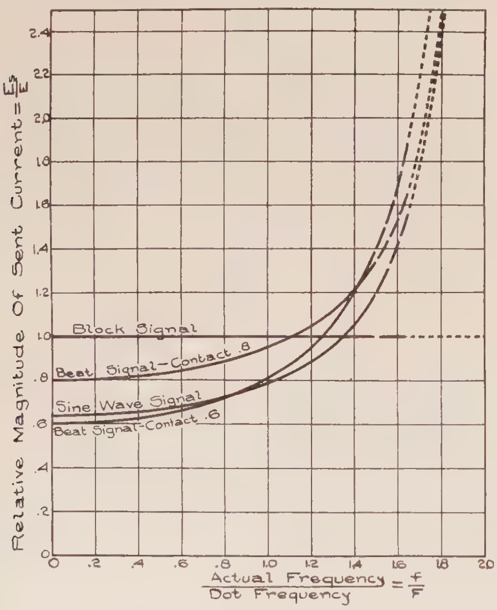

Fig. 17—Frequency Characteristics of Sending Signals

coil may be adjusted to have a free period of its own, the period being between 1.2 and 1.5 times the dot frequency.

If a magnifier is used of the Heurtley or selenium type, the hot wire of the former, or the selenium cell of the latter, has a certain amount of sluggishness which may have a decidedly beneficial effect in absorbing currents of the higher frequencies.

Frequency Characteristics of Sending Signals. Up to this point it has been assumed that the signal sent is of the so-called "block" type, as shown in curve 1, Fig. 9. There is another type of sending signal which is used to a considerable extent, namely the "beat" type of signal, curve 6, Fig. 9. Still another type has been proposed by Major-General G. O. Squier, namely the sine wave signal, curve 7, Fig. 9.

The characteristics of such signals may be studied in the same manner as parts of the circuit are studied. Frequency characteristics of these types of signals are shown in Figs. 16 and 17,[4] the latter figure being to a larger scale.

No general rule will be given as to which type of sending signals is best, the preference in any case being dependent upon a knowledge of the particular conditions which limit transmission. With beat signals smaller amounts of low-frequency currents are transmitted, so that the associated condensers and magnetic

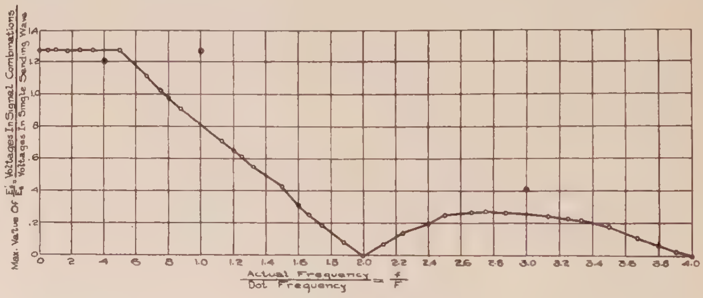

Fig. 18—Analysis of Sending Signal Combinations

shunt need not absorb as much of such currents. Block signals have advantages from the standpoint of duplex balancing, as will be evident later.

The Duplex Balance

Theory. Since cables are usually operated duplex and the balance is often the condition which limits operation of the cable, it is important to consider the theory and practise of balancing.

If there is present a small error in the balance, its effect is in general most severely felt when some irregular combination of signals is sent. In order to analyze this condition, the combination of signals may be considered to recur at regular intervals, and may then be broken up by the standard Fourier method into the sum of a number of separate sine waves. By

4. The development of these is given in the Appendix. The curves show only the *transient* characteristics of the signal. In the beat and sine wave signals, there is also a non-transient component which contains frequencies of 2, 4, 6, etc., times the dot frequency. Such frequencies may in general be neglected in studying transmission through the cable, for reasons given previously.

choosing various possible combinations of signals and analyzing them in this manner, we may determine what the maximum sine wave value of the sending voltage may be at any frequency. This maximum value will be designated E_s'.

Let it be assumed that the impedance of the cable is Z_0, and that the artificial line is so adjusted that the system would be perfectly balanced if the cable impedance were $Z_0\,(1 + \Delta)$ where Δ is a very small quantity. It can then be shown[5] that the deflection of the receiving instrument will be given by the expression

$$D_b = \frac{E_s'\, Z_0\, M\, \Delta}{(Z_0 + Z_s)\,(Z_0 + Z_r)} \qquad (3)$$

Now equation (2) gives the deflection of the receiving instrument at any frequency, when the sending battery is replaced by a sine wave of voltage of value E_s. By combining equations (2) and (3) we have,

$$D_b = 1/2\ .\ \frac{E_s'}{E_s}\ .\ \epsilon^{Pl}\ .\ D\ .\ \Delta \qquad (4)$$

A plot of the ratio E_s'/E_s, calculated by setting up various recurring combinations of signals as described above, is given in Fig. 18.[6] Plots of the quantity D under ideal conditions, and of $1/\epsilon^{Pl}$, were given in Figs. 12 and 13.

In order that duplex operation may be satisfactory, it is necessary that any deflection of the receiving instrument caused by off-balance, will be small as compared with the size of the signal itself. The precise amount permissible depends to some extent upon the individuality of the operator, so that no exact limit can be given. It may, however, be said that an approximate limit for deflection due to off-balance is 0.2 of the size of the dot signal. Now since each of the various combinations of signals contains several different frequencies, the effects of which are aggregated at times, it is necessary to apply a "factor of safety," which will here be assumed equal to 2. Taking these considerations into account, equation (4) may be put into the form

$$1/\Delta = \frac{E_s'}{E_s}\ \frac{D\ .\ \epsilon^{Pl}}{0.094} \quad \text{for recorder reception.} \qquad (5)$$

$$1/\Delta = \frac{E_s'}{E_s}\ \frac{D\ .\ \epsilon^{Pl}}{0.16} \quad \text{for relay reception.} \qquad (6)$$

Plots of values of $1/\Delta$ are given in Fig. 19. This figure shows the approximate degree of accuracy which the balance must possess at all frequencies, in order to permit operation of the cable previously referred to, at a dot frequency of ten cycles per second. It should

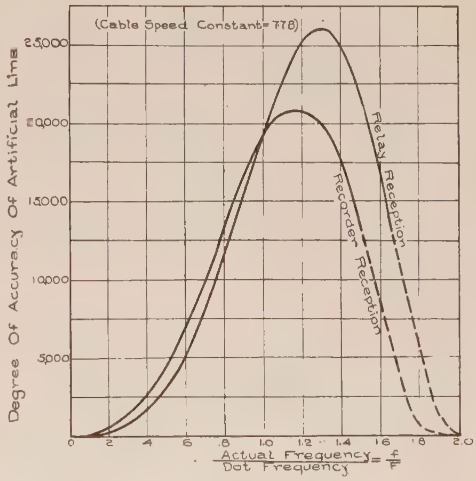

FIG. 19—ACCURACY REQUIREMENTS OF DUPLEX BALANCE

be noted that the curves in Fig. 19 have been built up on the basis of having apparatus which eliminates the higher unnecessary frequencies. With unfavorable operating apparatus far greater accuracy of the balance may be necessary.

Balance difficulties are an inherent property of a cable system operated duplex, for even if the cable is once balanced correctly, the balance is subject to change due to variations that occur in the temperature of the ocean bottom. In practise it is usually necessary to readjust the balance at least daily, in some cases several times daily. As shown above, a change in the impedance of the cable of one part in 25,000 is sufficient to be important. To maintain a balance correct at one frequency only to this degree of accuracy might not be especially difficult. The chief difficulty is, in fact, the maintenance of a balance correct to the required accuracy throughout a considerable range in frequency.

5. This equation may be readily proved for any special terminal circuit, by obtaining an expression for the current in each branch of the circuit when a sending voltage E_s' is impressed at the apex. A general proof may be obtained by breaking the impressed voltage into two parts, of which one part causes a current I_s to flow in line and in artificial line. The remaining part then acts to cause a current I_b, due to off-balance, to flow from the line into the receiving circuit. The deflection is M times I_b. It is assumed throughout that circuit conditions at the two ends of the cable are similar.

6. As examples of combinations chosen are the following: (1) Reversals; (2) Dot, dash, dash, dot, dash, dash, etc.; (3) Dot, dot, dash, dash, dot, dot, dash, dash, etc. A large number of other combinations was used. The curve in Fig. 18 is, of course, discontinuous. There are two points separate from the curve at $f/F = 1$ and at $f/F = 3$. (Balance disturbances from these particular frequencies are not likely to be more severe than from others, because it happens that these frequencies occur only together, and do not occur in combinations with the numerous other frequencies.) The above signal combinations may be assumed made up of "block" signals, or they may be assumed made up of "beat" or other shaped signals. If the latter, it will be found on trial that the values of E'_s are changed in amount, for any signal combination, by a ratio given by the ordinates of Figs. 16 and 17. But the value of E_s is also changed by the same amount, and the ratio E'_s/E_s is therefore independent of the type of signal. It should not be inferred from this that the type of sending signal has no influence on balance. The actual value of D in equations (4), (5), and (6), may be altered by changing the signal type, which may thus materially influence balance troubles. We are here concerned with the maximum values of the quantities in the equations, and it is not necessary to consider the angle of ϵ^{Pl}.

From the theory and curves given above, three important conclusions may be drawn regarding balancing, as follows:

(1) The effect of a given balance error upon the receiving instrument is dependent upon the *actual* shape of the frequency characteristic (Fig. 12) of the entire cable circuit. The actual shape of the characteristic becomes of rapidly increased importance at the higher frequencies.

(2) If there is a certain error in the balance, there can be nothing done *throughout the working range of frequencies*, to decrease its effect upon transmission, by altering the apparatus at either the sending or receiving end, excepting insomuch as the alterations change the shape of the useful transmitted signal.

(3) Any change in the apparatus at either the sending end or the receiving end of the cable, which decreases the magnitude of current transmitted through the cable *at frequencies higher than the working range*, without unduly affecting frequencies within the working range, is a distinct advantage in decreasing balance disturbances.

Artificial Lines. Every submarine cable, in addition to having resistance and capacity, has a certain amount of self-inductance and leakage. The latter factors are ordinarily too small to affect transmission through the cable, but are of considerable importance in balancing. The effective resistance and inductance vary with frequency, due to the characteristics of the sea-water return circuit,[7] and the capacity and leakage also vary with frequency, due to the behavior of the gutta-percha insulation.

The artificial line for balancing such a cable consists of a network of resistance and capacity, to which inductance may be added if desired. The network must be adjusted to have electrical characteristics that closely match those of the cable. The original adjustment may be a very tedious process, there being records of cases where as much as three months' work was done in obtaining a duplex balance for a single cable. Much of the early balancing was done without fully understanding the theory of balancing, and some ingenious appliances to artificial lines were developed by workers in the field, at a time when the electrical properties of the cable itself were incompletely understood. Fortunately, the theory is now better known so that the time required in balancing has been greatly cut down.

Artificial lines of any type are more or less sensitive to temperature changes, and are, therefore, usually placed in heat-insulated cabinets, sometimes located in rooms having special heat-insulated walls. In order to provide for convenient minor daily adjustments, it is customary to provide in addition a few small adjustable condensers and resistances, located near the receiving apparatus, and connected in the artificial line or in the bridge circuit.

The earliest type of artificial line was of the lumped variety, Fig. 20, used by Stearns. This artificial line was not successful, due probably to defects in design and construction.

Shortly afterwards, in 1875, the smooth type of artificial line was patented by Taylor and Muirhead.

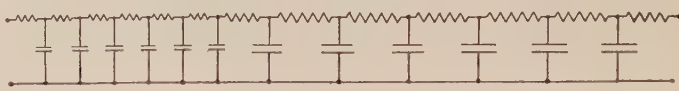

Fig. 20—Stearns Type of Artificial Cable
Capacity and resistance of each section adjustable

In this line (Fig. 21), the resistance of the line is made up of a zig-zag strip of tinfoil. This is insulated from the solid ground sheet of tinfoil by paraffined paper, thus forming the capacity of the line. The line is mounted in wooden boxes, having 10 to 21 microfarads per box, with terminals brought out which divide the line into sections of from one to three microfarads each. This type of line is especially sensitive to temperature changes.

A more recent type of artificial line has been patented by Dearlove. This line is made up of a large number of very small units of resistance and capacity, the latter being from 1/30 to 1/15 microfarad each. Neither the resistance nor the capacity is adjustable. The resistance and capacity are mounted together in boxes, similar to the type previously described.

With either of the types just described, the artificial line must be specially designed and constructed to match the cable with which it will be used, since the

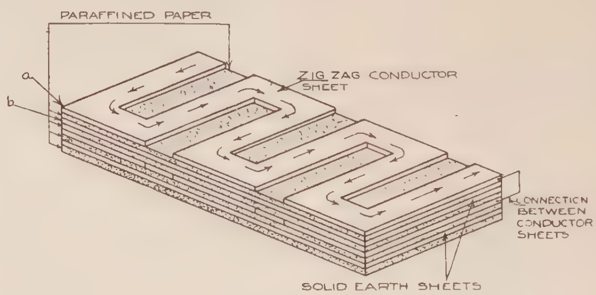

Fig. 21—Diagram of Muirhead Type of Artificial Cable

constants can be adjusted only in an indirect manner which introduces irregularities in the artificial line that have no duplicate in the cable.

A new type of artificial line[8] has been developed by the writer, with the object of overcoming the disadvantages of the types previously described. This artificial line is shown diagrammatically in Fig. 22, and contains resistances and condensers in fairly large lumps.

While it might seem that a lumped line of this type could not be made to balance a cable with constants

7. See J. R. Carson and J. J. Gilbert: "Transmission Characteristics of the Submarine Cable." *Journal of the Franklin Institute*, Dec. 1921.

8. Patents pending.

uniformly distributed, the actual condition is that the lumped arrangement is utilized to aid in balancing the inductance of the cable. It may readily be shown that the impedance of such network having a large number of resistances and condensers is

$$Z_{al} = \sqrt{\frac{R'}{j\,2\,\pi\,f\,C'} + R'\,R'' + R'^2/4} \qquad (7)$$

The surge impedance of a submarine cable with resistance, capacity and inductance is

$$Z_0 = \sqrt{\frac{R}{j\,2\,\pi\,f\,C} + L/C} \qquad (8)$$

From these it is apparent that a balance which is correct for all frequencies may be obtained if

$$R'/C' = R/C, \quad \text{and} \quad R'\,R'' + R'^2/4 = L/C \qquad (9)$$

An artificial line of this type has the additional advantage that it is readily constructed to be completely adjustable throughout its length. In practise the resistances and condensers are mounted in separate boxes, and the resistance of the line is made continuous with taps brought out at intervals. The resistance steps are small near the head of the line, and become increasingly larger away from the head. For adjustments a movable connector is used which is reliable and convenient to handle, and which does not introduce appreciable contact resistance. It is found that an adequate balance can be obtained with condenser units of two microfarads near the head of the line, and with considerably larger units toward the rear of the line. The resistances in series with the condensers need little if any adjustment, and are only necessary near the head of the line.

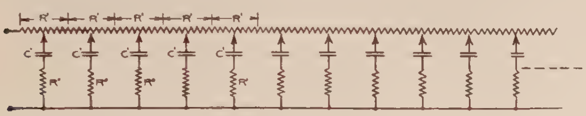

Fig. 22—Adjustable Type of Artificial Line

Kelvin's *KR* Law

This law, formulated early in the history of the science, states simply that the operating speed of the usual type of cable is inversely proportional to the product of its capacity times its resistance, the letters "*KR*" being an old symbol for this product. Expressed in another way, the law states that the product of speed times the "*KR*" is a constant. With speed expressed in letters per minute, cable resistance in ohms, and capacity in farads, this product is termed the "speed constant" of the cable, and is widely used.

That the *K R* law is approximately true is immediately evident from the preceding theory [see equation (2)]. The amount of energy which is transmitted through the cable is directly dependent upon the product of frequency times resistance times capacity, and if there is a definite minimum permissible amount of received energy, then there must be a definite value of the above product.

Obviously, the above does not take into account the fact that different conditions may in different cases act to limit the speed of a cable. The "speed constant" is therefore not a definite fixed value, but varies in different cases, and is in fact a measure of the efficiency of operation. With recorder reception a speed constant of 500 to 550 is usual. With magnifier reception and duplex operation, speed constants from 600 to 800 or higher are regularly obtained. A speed constant as high as 1200 has been commercially attained over a cable which was operated in one direction only, and was therefore free from balance troubles.

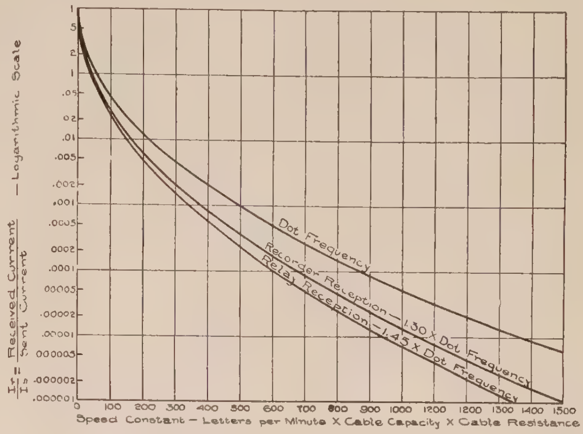

Fig 23—Decrease of Current in Cable

In order to examine further the validity of the *K R* law, the effects of the different limiting conditions to cable operation will be considered separately.

(1) If conditions are such that the speed of a cable is limited only by the sensitiveness of available receiving equipment, the *K R* law forms an approximate guide only. This condition is not now of sufficient importance to justify a detailed discussion. It may be said, however, that of two cables of unequal length a somewhat higher speed constant (although a lower speed) will in general be obtained over the longer cable, for the reason that a given receiving instrument can be adjusted to have higher sensitiveness when used for operation at low speed.

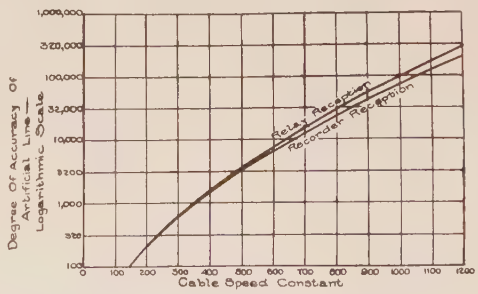

Fig. 24—Relative Accuracy Requirements of Duplex Balance

(2) If the speeds of two cables are limited only by

the duplex balance, and the cables are subjected to the same percentage balance variations and have equally efficient terminal equipment, then the $K R$ law is an accurate guide to their relative speeds. This is evident from equations (**5**) or (**6**), for with any given value of f/F, each term of the equation is constant, and the quantity $P l$ is therefore constant.

(3) If the speeds of two cables are limited only by the presence of extraneous current caused by small equal extraneous voltages impressed at the end of the sea-earth, then it will also be found that the $K R$ law accurately applies. It is again assumed that equally efficient terminal equipment is used. Two such cables subjected to the same extraneous voltage will have the same speed constant, while if the two cables are subjected to different amounts of extraneous voltage, then the one subjected to the smaller extraneous voltage will have the higher speed constant.

The ratio of received current to sent current in cables operated at different speed constants is shown in Fig. 23. It will be noted that a small change in the speed constant requires considerable increase in the sensitiveness of receiving equipment. The approximate degree of accuracy that the duplex balance must possess with different speed constants, assuming favorable terminal apparatus, is shown in Fig. 24.

In conclusion the writer desires to acknowledge the valuable assistance which he has received in the preparation of this paper, from Mr. C. H. Cramer and Mr. W. D. Cannon.

Appendix

In this Appendix is given the fundamental theory of the method of analysis used in the body of the paper. While the general plan has previously been to assume the shape of the received current to be known, and to determine the frequency characteristic from the known current, the method also provides for determining the received current or voltage when the frequency characteristic is known, as shown below. The most useful case is to determine the received current caused by the application of a suddenly impressed steady voltage, yet the method is applicable for determining effects caused by any general transient shape of voltage or current, in cable or other electrical circuits.

The frequency characteristics have previously been considered to be functions of the frequency, and to show the magnitude and the time lead or lag of the wave. In the Appendix the frequency characteristics will be considered to be functions of $p = 2 \pi f$, and will show the sine and cosine components of the wave separately.

In order to calculate the received current or voltage, the transient source is assumed replaced by a continuous sine wave source, and a calculation is in general made of the received voltage or current for all values of frequency from zero to infinity. The real and imaginary components are calculated separately, and are denoted respectively by u and v. A formula for the received voltage or current caused by a suddenly impressed continued voltage is given in equation (**10**).

In difficult cases the necessary integrations are too complicated to be solved analytically, and it is necessary to resort to a graphical or mechanical method of integration. A form of harmonic analyzer is especially applicable.

Notation

t = time

$p = 2 \pi \times$ frequency

y = height of transient curve (function of t)

s = sine component of frequency characteristic (function of p)

c = cosine component of frequency characteristic (function of p)

u = real component of received sine wave (function of p)

v = imaginary component of received sine wave (function of p)

$j = \sqrt{-1}$

$a, b, g, k, m, n, A, P, T,$ constants

R = resistance

L = inductance

E = voltage

I = current

Theory

The method is a development of Fourier's series. Referring to Fig. 25, the Fourier expression for a single valued continuous curve of any shape between the limits of $-2k$ and $+2k$ is,

$$y = a_1 \sin \frac{\pi t}{2 k} + a_2 \sin \frac{2 \pi t}{2 k} + a_3 \sin \frac{3 \pi t}{2 k} + \ldots$$

Fig 25

$$+ b_0 + b_1 \cos \frac{\pi t}{2 k} + b_2 \cos \frac{2 \pi t}{2 k}$$

$$+ b_3 \cos \frac{3 \pi t}{2 k} + \ldots \quad (1)$$

A curve such as shown in Fig. 26 may be expressed by the simpler form,

$$y = a_1 \sin \frac{\pi t}{2 k} + a_3 \sin \frac{3 \pi t}{2 k} + \ldots$$

$$+ b_0 + b_1 \cos \frac{\pi t}{2 k} + b_3 \cos \frac{3 \pi t}{2 k} + \ldots \quad (2)$$

$$= \sum_{1, 3 \ldots}^{\infty} a_m \sin \frac{m \pi t}{2 k} + b_0 + \sum_{1, 3, \ldots}^{\infty} b_m \cos \frac{m \pi t}{2 k} \quad (3)$$

In Fig. 26, the two halves of the curve are similar in shape, but inverted. The portion between $-k$ and $+k$ is the part in which we are especially interested. The value of k may be made as large as desired, so that in practise any shape of continuous curve may be expressed by (3).

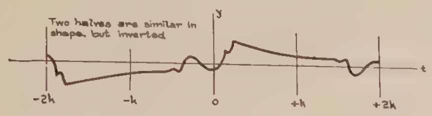

FIG. 26

An additional limitation upon the curve will now be made in order to simplify further the mathematics. It will be assumed that the curve is horizontal, as shown in Fig. 27, excepting for a small portion in the neighborhood of the vertical axis. The value of k will later be assumed increased indefinitely, as in Fig. 28. In the remainder of this theory, it is assumed that the transient under investigation is of the general type shown in Fig. 28. This limitation does not prevent the investigation of those types of transients in which we are interested, as is shown later.

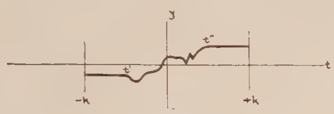

FIG. 27

Referring to equation (3), the value of m takes every odd integer value from one to infinity. By assuming k increased indefinitely, (3) may be replaced by an equation containing integrals, and becomes of the form

$$y = 1/\pi \int_0^\infty s \sin pt\, dp + 1/\pi \int_0^\infty c \cos pt\, dp + b_0, \quad (4)$$

in which $\frac{m\,\pi}{2\,k}$ has been replaced by p, $k\,a_m$ has been

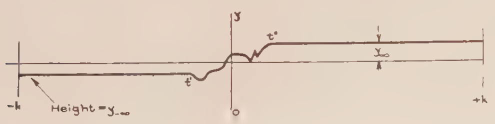

FIG. 28

replaced by s, and $k\,b_m$ has been replaced by c. The quantities s and c are functions of p, and constitute the *frequency characteristic* referred to previously.

For each type or shape of transient curve there is a pair of quantities s and c, which correspond to the one transient curve only. The frequency characteristic is independent of the actual value of k, provided that k is large. Equation (4) enables the transient to be determined when the frequency characteristic is known. Equations (8), below, enable the frequency characteristic to be determined when the transient itself is given. Equations (4) and (8) are the fundamental equations of this theory.

To develop the latter equations, we have the well-known equations for determining the constants of Fourier's series,

$$a_m = \frac{1}{2\,k} \int_{-2k}^{2k} y \sin \frac{m\,\pi\,t}{2\,k}\, d\,t$$

$$b_m = \frac{1}{2\,k} \int_{-2k}^{2k} y \cos \frac{m\,\pi\,t}{2\,k}\, d\,t \quad (5)$$

$$b_0 = \frac{1}{4\,k} \int_{-2k}^{2k} y\, d\,t$$

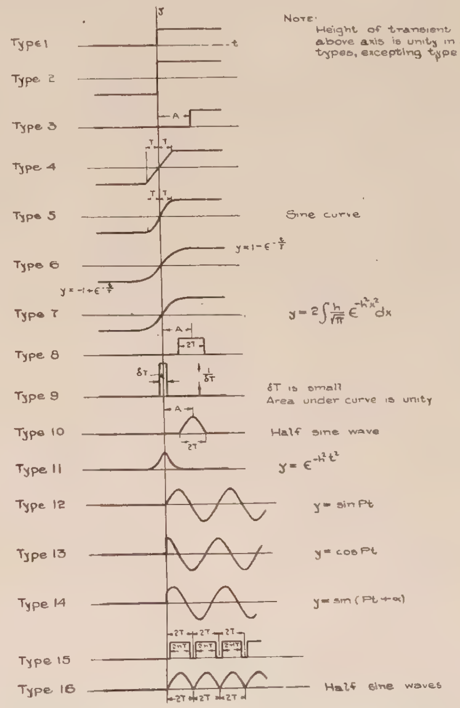

FIG. 29—TRANSIENT TYPES

Now since we are considering only odd harmonics, the first of these may be written

$$a_m = 1/k \int_{-k}^{k} y \sin \frac{m\,\pi\,t}{2\,k}\, d\,t \quad (6)$$

In evaluating the limits, it will be noted that the sine is at its highest or at its lowest value at each limit. It is not necessary to carry the limits to the values of $-k$ or $+k$; instead it is only necessary to begin the integration from some point at the left of t', Fig. 28, and carry it to some point to the right of t''—providing that in each case the integration is stopped at a point where the sine is at its maximum or at its minimum, *i. e.*, at a point where the cosine is zero.

A similar simplification might be made directly of the second of equations (5) for the special case where $b_0 = O$. In the case where $b_0 \neq O$, the case is less

simple. It may, however, be shown that in general, when k is large

$$b_m = 1/k \int_{-k+k/m}^{k-k/m} y \cos \frac{m \pi t}{2k}\, dt \tag{7}$$

At each of these limits the sine is zero, and it is again necessary only to carry the integration from some point at the left of t', to some point at the right of t''. As k is increased indefinitely, the above equations take the form below, where substitutions as before have been made

$$\left.\begin{aligned} s &= \int y \sin pt \; dt \text{ between limits where } \cos p\,t = O, \\ c &= \int y \cos pt \; dt \text{ between limits where } \sin p\,t = O, \end{aligned}\right\} \tag{8}$$

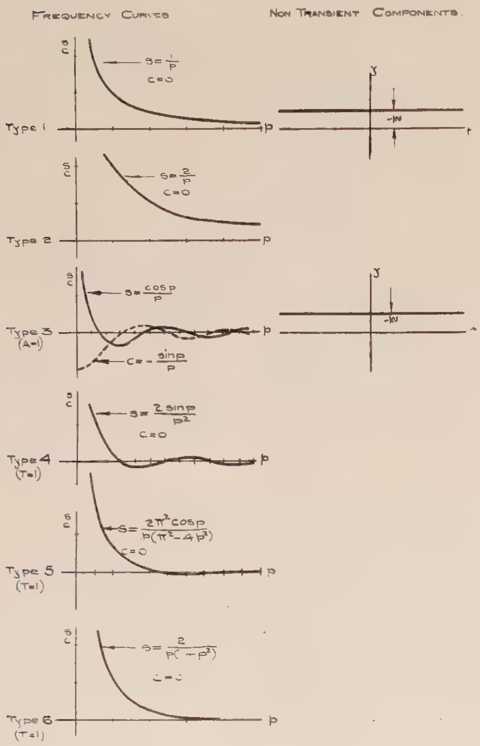

Fig. 30—Frequency Characteristics

each integration to be carried *through* the transient.

$$b_0 = \frac{y_{-\infty} + y_{\infty}}{2}$$

In Fig. 29 are shown examples of a number of types of transients, and in Table I are given formulas for the frequency characteristics for the various types. These formulas were calculated with the aid of equations (8). If the values given in Table I are substituted in equation (4) and the integration is carried out, the original transient will be obtained. Plots of a number of the frequency characteristics are given in Figs. 30 and 31.[9]

9. It should be noted that the characteristics shown in Figs. 12, 16 and 17 of the body of the paper are comparative rather than absolute characteristics. They show the ratio at each frequency of the characteristics of the transient under consideration, to the characteristic of transient type 1.

Further explanation is necessary in connection with transient types 12 to 16 inclusive. In calculating the frequency curve of type 12, the transient is assumed

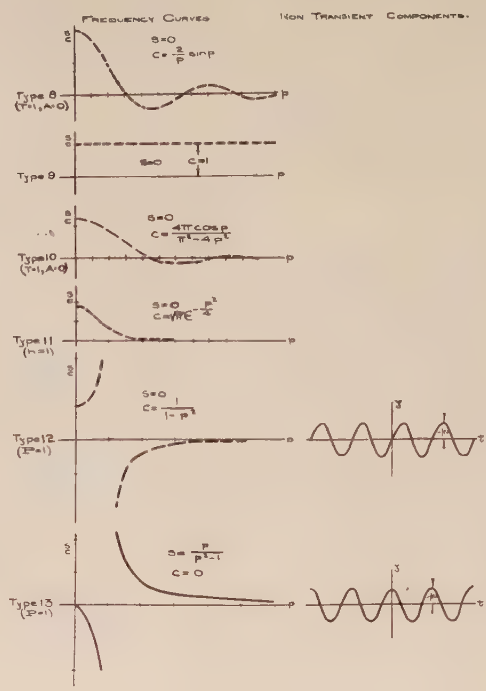

Fig. 31—Frequency Characteristics

TABLE I
CONSTANTS OF FREQUENCY CHARACTERISTICS FOR VARIOUS TRANSIENTS

Transient Type	s = sine component	c = cosine component	Non-transient component
1	$1/p$	0	1/2
2	$2/p$	0	0
3	$(1/p) \cos p\,A$	$-(1/p) \sin p\,A$	1/2
4	$\dfrac{2 \sin p\,T}{p^2\,T}$	0	0
5	$\dfrac{2\,\pi^2 \cos p\,T}{p\,(\pi^2 - 4\,p^2\,T^2)}$	0	0
6	$\dfrac{2}{p\,(1 + p^2\,T^2)}$	0	0
7	$(2/p)\,\epsilon^{-p^2/4h^2}$	0	0
8	$\dfrac{2 \sin p\,T}{p} \sin p\,A$	$\dfrac{2 \sin p\,T}{p} \cos p\,A$	0
9	0	1	0
10	$\dfrac{4\,\pi\,T \cos p\,T}{\pi^2 - 4\,p^2\,T^2} \sin p\,A$	$\dfrac{4\,\pi\,T \cos p\,T}{\pi^2 - 4\,p^2\,T^2} \cos p\,A$	0
11	0	$(\sqrt{\pi}/h)\,\epsilon^{-p^2/4h^2}$	0
12	0	$\dfrac{P}{P^2 - p^2}$	$(1/2) \sin P\,t$
13	$\dfrac{p}{p^2 - P^2}$	0	$(1/2) \cos P\,t$
14	$\dfrac{p \sin \alpha}{p^2 - P^2}$	$\dfrac{P \cos \alpha}{P^2 - p^2}$	$(1/2) \sin (P\,t + \alpha)$
15	$\dfrac{\sin n\,p\,T}{p \sin p\,T}$	0	Continuous, similar in form to right-hand part of original, and half the height.
16	$\dfrac{2\,\pi\,T \cot p\,T}{\pi^2 - 4\,p^2\,T^2}$	0	

to be built up as shown in Fig. 32. The upper part is the transient component; the lower part is a non-transient component consisting of a continuous sine wave of half amplitude. The height of the transient component is assumed to be a double exponential curve as shown. The frequency characteristic of this transient is first calculated, after which the value of g is increased indefinitely. At the same time, g must be considered to remain small as compared with k. In this manner the limiting value given in Table I was obtained. The values in Table I for transient types 13, 14, 15, and 16 were calculated in a similar manner. The non-transient components of types 15 and 16 are themselves irregular in shape, and may be broken up by the standard Fourier method into the sum of a series of continuous sine waves. Thus the non-transient component of type 15 is equivalent to

$$n/2 - \frac{\sin n\,\pi}{\pi} \cos\frac{\pi\,t}{T} + \frac{\sin 2\,n\,\pi}{2\,\pi} \cos\frac{2\,\pi\,t}{T} - \ldots$$

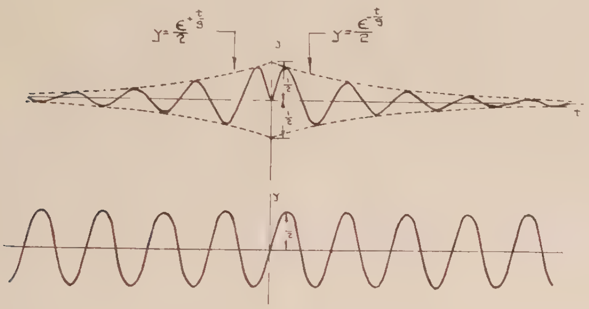

FIG. 32—DEVELOPMENT OF TRANSIENT TYPE 12

APPLICATION TO ELECTRICAL PROBLEMS

Referring now particularly to transient type 1, the preceding theory shows that it may be regarded as the sum of an infinite number of sine waves, of heights equal to $1/p$, added to a non-transient component of height 1/2. The sine waves are individually attenuated in the electrical circuit in a manner which can be calculated by ordinary alternating-current theory, thus obtaining the frequency characteristic for the resultant effect at the receiving end. Then from equation (4) the shape of the received current is obtained.

Let it now be assumed that the transient source is replaced by a sine wave of voltage of frequency $p/2\,n$. At the receiving end, let u be the component in phase with the impressed wave, and let v be the component at 90 deg. Then the frequency characteristic of the received current will be

$$\left.\begin{aligned} s' &= u/p \\ c' &= v/p \end{aligned}\right\} \qquad (9)$$

Substituting in equation (4), we have the formula for the received current caused by an initial transient of type 1

$$y = 1/\pi \int_0^\infty \frac{u}{p} \sin pt\,dp + 1/\pi \int_0^\infty \frac{v}{p} \cos pt\,dp + u_0/2 \qquad (10)$$

The effect of the non-transient component of the initial transient has been calculated separately, and included in the formula.

In the general case, applicable to any initial type of transient, let s and c represent the initial frequency characteristic. Then the characteristic of the resultant transient will be

$$\left.\begin{aligned} s' &= s\,u - c\,v \\ c' &= c\,u + s\,v \end{aligned}\right\} \qquad (11)$$

Substituting in equation (4), we have the formula for the resultant transient caused by any initial type of transient

$$y = 1/\pi \int_0^\infty (s\,u - c\,v) \sin pt\,dp + 1/\pi \int_0^\infty (c\,u + s\,v) \cos pt\,dp \qquad (12)$$

If the initial transient is composed, in part, of a non-transient component, the effect of the latter must be calculated separately, and added to the result of equation (12).

The effect caused by suddenly impressing a continued sine wave (transient type 12) is given by the formu

$$y = -1/\pi \int_0^\infty \frac{P\,v \sin pt\,dp}{P^2 - p^2} + 1/\pi \int_0^\infty \frac{P\,u \cos pt\,dp}{P^2 - p^2} + u_P \frac{\sin P\,t}{2} + v_P \frac{\cos P\,t}{2} \qquad (13)$$

EXAMPLES

1. Let it be required to obtain the value of current in a circuit containing inductance and resistance, caused by impressing a voltage transient of type 1.

The current through such a circuit caused by a sine wave of voltage is

$$I = \frac{E}{R + j\,p\,L} = E\,\frac{R - j\,p\,L}{R^2 + p^2\,L^2} \qquad (14)$$

From this we obtain

$$u = \frac{R\,E}{R^2 + p^2\,L^2}\,, \qquad v = \frac{-\,p\,L\,E}{R^2 + p^2\,L^2}\,,$$
$$u_0 = E/R \qquad (15)$$

Substituting in equation (10) gives

$$y = 1/\pi \int_0^\infty \frac{R\,E}{p\,R^2 + p^3\,L^2} \sin pt\,dp - 1/\pi \int_0^\infty \frac{L\,E}{R^2 + p^2\,L^2} \cos p\,t\,d\,p + \frac{E}{2\ R} \qquad (16)$$

$$= \frac{E}{2R}(1 - \epsilon^{-Rt/L}) - \frac{E}{2R}\epsilon^{-Rt/L} + \frac{E}{2R} \qquad (17)$$

$$= E/R\,(1 - \epsilon^{-Rt/L}) \qquad (18)$$

Equation (17) was obtained with the aid of a table of definite integrals.

2. The current through an inductance and resistance in series, caused by suddenly impressing a continued sine wave of voltage may be obtained by substituting in equation (13) the values of u and v from equation (15). The result is

$$I = \frac{E}{R^2 + P^2 L^2}(P\,L\,\epsilon^{-Rt/L} + R \sin P\,t - P\,L \cos P\,t) \qquad (19)$$

Energy Front of Electric Circuits

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As there has been recently some discussion of the position of the energy front in an electric circuit, and as this discussion mainly consisted in quoting mathematical authorities against each other, it may be of interest to the reader who does not care to go into the mathematics of it, to discuss in non-mathematical terms the energy travel in the space surrounding a conductor carrying electric current.

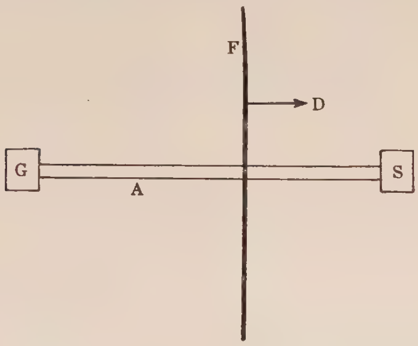

Fig. 1

It is obvious that there is no real disagreement between the mathematical conclusions, but the apparent disagreement is merely the result of misinterpretation.

Assume electric power is transmitted from a generating station G over a transmission line A into a receiving station S.

1. Let us first consider the ideal case of no energy loss, that is, assume a perfect conductor of zero resistance, and that all the energy sent out by the generating station G, arrives at the receiving station S. The electric field of the conductor and the energy carried by it must then move parallel to the conductor, as shown by the arrow D in Fig. 1; that is, the wave front of the energy travel, or "energy front" is perpendicular to the conductor, as shown by F in Fig. 1. This is obvious, as only the energy moving parallel with A can arrive at S.

2. There is however inevitably some energy dissipated in the ohmic resistance of the conductor A. Physically, this appears as a slowing down of the speed of travel of the energy front in the conductor, behind that in free space[1], so that the energy front in the conductor, F, in Fig. 2, lags behind the energy front F_0 in surrounding space. This means that the energy front near the conductor cannot remain perpendicular but bends back, as shown in Fig. 3, and the direction of energy travel near the conductor converges towards the conductor as seen by the arrows in Fig. 3.

3. On a perpendicular, the distance $a\,G$ Fig. 4, at some distance from the conductor A, is greater than the distance $b\,G$, near the conductor A. The energy front therefore cannot remain perpendicular to the conductor A at greater distance from the conductor but must curve back, as shown by the dotted line in Fig. 4, so that the distances (along the stream lines) from the source of energy to the parts of the energy front in space are the same.

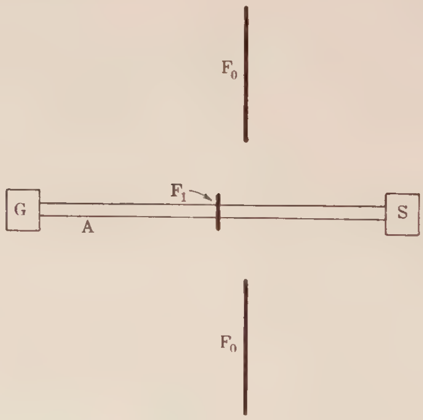

Fig. 2

The complete shape of the energy front by (1), (2) and (3) thus is like Fig. 5. That is, perpendicular at some distance F_0 from the conductor A, and bent

1. From the velocity of light $1/\sqrt{L\,C} = 3 \times 10^{10}$ cm. per sec. by the factor

$$\sqrt{1 - \frac{4\,r^2}{z^2}}$$

where $z = \sqrt{L/C}$ is the surge impedance of the circuit and L, C and r the inductance, capacity and resistance per unit length.

back nearer to the conductor, at F_1 as well as further away from the conductor at F_2. That is, the energy flow is parallel to the conductor at some distance from it, as shown by arrow D_0; converging towards the conductor near it, at D_1, and diverging from the conductor at greater distance from it, D_2.

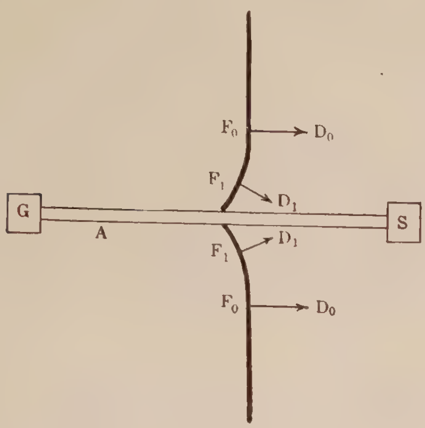

FIG. 3

Thus far we have the viewpoint of the scientist. Next, that of the engineer comes in. Engineering is science applied to the use of man. The engineer thus resolves the phenomena into components according to their relation to man, useful or wasteful.

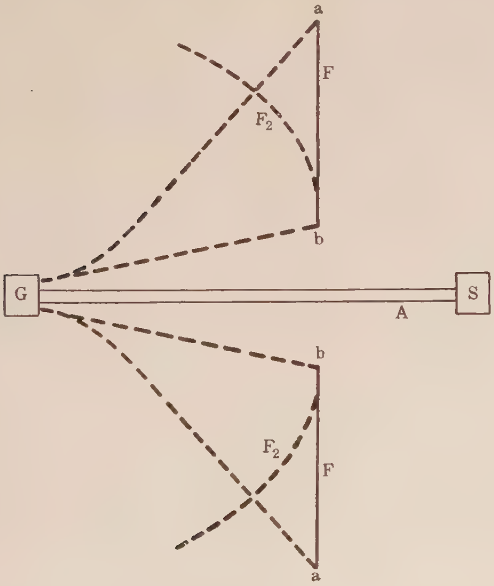

FIG. 4

Thus the energy flow in Fig. 5 may be resolved into components; those parallel with the conductor, D_0, D_{01}, D_{02} of Fig. 6, and those perpendicular to the conductor D_1' and D_2'. The former give the energy which arrives at the receiving station S, the *useful energy* for which the conductor was erected[2]. The latter give the energy which does not arrive at its intended destination, but is wasted, absorbed by the conductor A and dissipated as heat: D_1', or scattered as radiation through space D_2'.

We separate the two radial components, since their economic relation to us is different. The inward component D_1' is responsible for the amount of conductor material required, the outward component D_2' does not require line copper, but may lead to interference with other circuits. Furthermore, in other circuits, other ones of the components of energy flow may be useful or wasteful. Thus in the antenna circuit of radio communication, the radially outward component D_2' is the useful energy which carries the message, while the radially inward component D_1' is waste energy.

The next step for the engineer is to calculate separately the components, so as to make the useful ones large, the wasteful ones small.

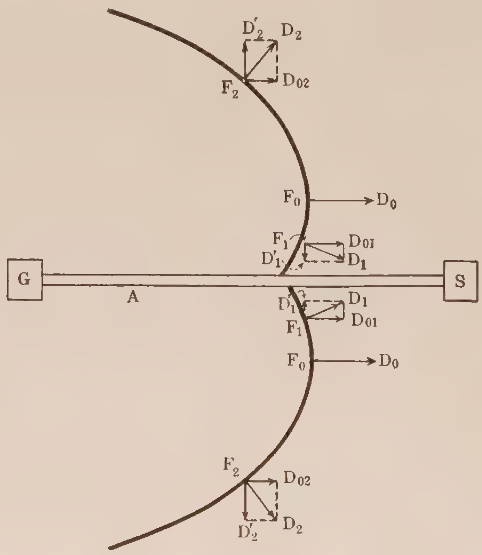

FIG. 5

Thus in calculating the radiation component D_2', we consider only the radially outward energy flow D_2', but disregard the parallel flow D_0 and D_{02}, that is, consider the current phase as constant throughout the conductor A, and the conductor thus is the radiator.

It is obvious that ultimately the radiated energy as well as the transmitted energy and the energy dissipated as heat in the conductor come from the generating station G.

Under transmission line conditions at machine frequencies, the radiation component is negligible, so that Fig. 3 sufficiently represents the energy wave; D_2' becomes the dominating component however in radio communication.

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2. This useful component of energy flow we may again divide into two components, the one which remains at the receiving station, the true power; and the one which oscillates between receiving station and generating station, the reactive power.

Five Hundred Tests on the Dielectric Strength of Oil

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While developing a dependable method of taking experimental data with a sphere gap in transil oil, considerable study was made of the behavior of oil under disruptive dielectric stress. The following notes on the dielectric strength of oil are offered as evidence that the nature and character of the dielectric breakdown of oil may be entirely different from that of air.

Five hundred successive breakdowns were taken on a sphere-gap in oil at the same gap setting. Because of the well known inconsistency of breakdowns in oil these observations showed wide variation. A curve was plotted to show the relation between the breakdown voltage and the number of breakdowns at each voltage. If the disruptive breakdown of oil is due to the voltage exceeding the dielectric strength of the oil, as is the case with air, it should be possible to represent such a curve of probable error, or "probability curve" as it is usually called, by an exponential equation. In the following paper this is seen to be impossible, the most representative exponential curve being higher than the observations at higher voltages. The explanation is offered that this discrepancy is caused by foreign particles of low dielectric strength being drawn into the gap and that therefore the dielectric strength of oil differs from that of air in that it does not represent the true breakdown value of the oil but is instead a measure of the presence of foreign particles in the oil.

AIR gives a definite dielectric strength (30 kv. per cm. at 0 deg. cent., 76 cm. barometer), as shown by the work of Peek, Ryan and Whitehead, and disruptive tests in air gap give consistant results within the errors of observation. Not so, however, oil. In spite of the greatest care taken to reproduce identical conditions as nearly as possible, successive disruptive tests made on the same oil differ from each other far beyond the possible errors of observation.

To study this phenomenon of the erratic behavior of oil, and its possible cause and explanation, 500 successive tests were made with the same sample of oil under constant conditions. A large sample of oil was chosen, the circuit opened immediately after each discharge, and the discharge current limited by resistance in the low-tension circuit, so as to give little deterioration of the oil (by carbonization, etc.) during the test, and the deterioration allowed for, as further described. In commercial testing of oil, usually small flat disks with sharp edges are used as electrodes, to give a combination of the effect of a uniform field and the edge effect. When, however, determining the dielectric strength of a material, as nearly a uniform field as possible must be used, and a field which can be accurately calculated. This is the case with the field between spheres at moderate distance from each other. Therefore a sphere gap was used. In view of the high dielectric strength of oil, and to avoid excessive voltage a gap of two mm. was used between spheres of one cm. diameter. The spheres were of molybdenum, as experience had shown that tungsten and molybdenum are least liable to pitting under the discharge. After each test the spheres were wiped off in the same manner, under the oil, by a wiper kept under the oil and the oil allowed to settle the same length of time before each test. The oil was filtered hot through a number of layers of hot and dry filter paper, and carefully protected from dust and moisture. The same source of voltage supply, 60-cycle alternating current, and the same transformers were used, and the voltage controlled by the potentiometer method (shunt and series resistance), being the method least liable to give voltage wave distortion. The voltage was raised at the same constant rate in all tests, one volt per second on the low-voltage side of the transformers, at a transformation ratio of 580; in short, the conditions were kept as nearly the same as could be determined, and much more uniform than is necessary to get consistent results in air. The voltage was read on the low-tension side of the tranformers, as this checked to be accurate within less than one per cent.

Nevertheless, the observed breakdown voltages in the successive tests differed enormously, and in entirely erratic manner, by as much as a hundred per cent.

In spite of the large volume of oil used, there was a slight deterioration which became noticeable after more than 200 tests. Therefore the tests were divided into five successive groups of one hundred each, and the average value calculated for each hundred. This gave the average breakdown voltages (low-tension side, ratio 580 to 1) for the successive five sets of hundred tests,

$$e_0 = 95, 96, 91, 89, 86$$

showing a slight and increasing deterioration.

To allow for this, in working up the tests, not the voltage e of each individual test was used, but its difference from the average voltage of the hundred tests to which it belonged, that is $x = e - e_0$.

Using these differences $x = e - e_0$, the effect of deterioration was sufficiently eliminated, and all 500 readings could be combined. The number of breakdowns y observed at each voltage difference x is given in the second column of the following table, and plotted as y in Fig. 1, marked by circles, with x as abscissas.

As seen, the values of y do not lie on a smooth curve, but vary erratically, but their grouping is similar to that which would be expected from a set of values scattering by probability around an average value.

To be presented at the 10th Midwinter Convention of the A. I. E. E., New York, N. Y., February 15-17, 1922.

TABLE I

$x = e - e_0$	y:	$x = e - e_0$	y:	$x = e - e_0$	y:	$x = e - e_0$	y:
− 31	0						
− 30	2	− 17	1	− 4	14	+ 9	20
− 29	0	− 16	2	− 3	19	+ 10	16
− 28	2	− 15	0	− 2	19	+ 11	10
− 27	0	− 14	5	− 1	20	+ 12	14
− 26	0	− 13	11	0	32	+ 13	10
− 25	1	− 12	10	+ 1	14	+ 14	9
− 24	1	− 11	7	+ 2	17	+ 15	6
− 23	3	− 10	14	+ 3	30	+ 16	2
− 22	1	− 9	11	+ 4	25	+ 17	2
− 21	1	− 8	8	+ 5	23	+ 18	1
− 20	4	− 7	14	+ 6	18	− 19	0
− 19	2	− 6	23	+ 7	23	+ 20	2
− 18	2	− 5	9	+ 8	20	+ 21	0

A number of probability curves were calculated by the Σ Δ method[1], in the attempt to fit the relation between x and y.

It was found that all the data could not be represented by one probability curve, but the probability curve calculated from the positive x values—that is, the voltage e above the average e_0—did not fit the negative x values, and inversely.

However, the y values from $x = +9$ to $x = -22$, comprising 84 per cent of the observations, can be well represented by the probability curve

$$y = 24.8\, \epsilon^{-0.0051(x-3)^2}$$

This probability curve is shown in Fig. 1. It fits the observations fairly well, except that for high values of voltage, the observations drop below the probability curve, the more so the higher the voltage; that is, the breakdown occurs at lower voltage than given by the probability curve. At very low voltages, the observation seem to be higher than the probability curve, but in this range their number is too small to be conclusive.

The explanation which suggests itself is as follows:

The disruptive breakdown of oil under dielectric stress is not due to the voltage exceeding the dielectric strength of oil, as is the case in air, but is due to something being carried into the dielectric field, or being produced in the dielectric field, which weakens the dielectric strength so as to cause a premature breakdown. The breakdown therefore does not occur at a definite value of voltage, as is the case with air, but at values scattered over a wide range of voltages in accordance with the probability curve of the appearance of such dielectrically weaker material in the field. What this material is, we do not know; it may be moisture, or dissociation products of the oil, or olefines or fats or fatty acids, or dust or fibers, or combinations of them, in solution or collodial solution or suspension in the oil.

On the higher-voltage part of the probability curve, the approach to the true dielectric strength of oil increases the frequency of breakdown beyond the probability curve, and thus causes the observations to drop below the probability curve. This also causes the maximum point of the probability curve to be at a higher voltage than the average breakdown voltage.

This opens up a very interesting, and in view of the great industrial importance of oil as insulating material, important field for further investigation. Hitherto, usually the assumption has been made that the dielectric breakdown of oil and other similar insulations is of the same nature and character as that of air, that is, it depends upon a definite breakdown value, though the experimental behavior of oil in the dielectric field, such as its erratic breakdown voltage, the very pronounced time lag, etc., point to the possibility that the mechanism of the dielectric breakdown of oil and similar materials is materially different from that of air.

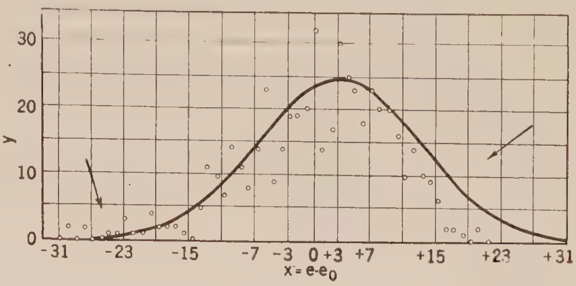

FIG. 1—PROBABILITY CURVE OF DIELECTRIC BREAKDOWN OF TRANSIL OIL AND THE PLOTTED VALUES OF THE OBSERVED TESTS.

The ordinates (y) are the number of punctures that have been found, by observation, to take place at each value of the abscissas.

The abscissas are the difference between the particular average value and the actual value of puncture voltage for each test. The numerical values are given in low-tension volts. The actual voltage difference may be found by multiplying the particular abscissa by the transformer ratio, 580 to 1. Thus the maximum difference from the average breakdown (say 55,000 volts = 95 × 580) is minus 31 volts which is actually 18,000 volts less than the average puncture value of 55,000 volts.

On the other side of zero, the highest puncture voltage above the average is 21 which corresponds to 12,200 volts = 21 × 580. It should be noted that all the observations in this neighborhood fall far below the solid line, which is the mathematical probability curve given by the particular formula

$$y = 24.8\, \epsilon^{-0.0051(x-3)^2}$$

This equation, by several trials, was found to be the nearest obtainable representation of all the values given by the tests and shown by the circles.

Since the return of Alsace and Lorraine to France, efforts have been made to complete the system of navigable waterways which link up these provinces with the main arteries of French navigation. Among these is the Marseilles-Rhone canal, to connect Marseilles with the Rhone at Arles. This canal, which was begun in 1911, will have a length of 50 miles, and will enable the river barges at present plying on the Rhone to reach the port of Marseilles directly, whereas at present they are obliged to come by sea from the Port of St. Louis, crossing the Gulf of Fos. The construction includes a tunnel, said to be the widest in the world, measuring 72 feet from side to side, with a length of 4⅜ miles, 45 feet high, and providing for a canal 13 feet deep. The tunnel was entirely pierced last June, and all that remains to be done is the removal of the central supports and the excavation of the canal itself. The canal is expected to be completed in 1925.

1. Steinmetz, "Engineering Mathematics," Chapter VI C.

The Petersen Earth Coil

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Review of the Subject.—*Accidental arcing grounds on transmission lines constitute the foremost problem to be solved in the transmission of electrical energy over great distances. There has come into use to a limited extent, arcing ground suppressors. This device consists in principle, of a switch in the station which is automatically closed in parallel with the accidental arc at any point out on the system. The parallel path through the switch shunts the current from the arc and thereby extinguishes the arc. This development is not yet completed.*

This paper gives the results of some experiments on an entirely different device for suppressing accidental grounds—a device that was first advocated by Prof. W. Petersen of Darmstadt, Germany. The essential part of this new apparatus is a suitable reactor c nnected between the neutral of the circuit and ground. This reactance is chosen of such a value as to neutralize the capacitance of the circuits when an accidental ground of one phase takes place. Under th s acc dental condition the reactor is electrically in parallel with the active capacitances and, by the well-known fundamental law, the only current that flows to the combination of the inductance and capacitance in parallel is the current necessary to supply the energy loss in the combination. The simplified equivalent conditions are shown in Fig. 4. This energy current can be made very small and it is this relatively small current that passes through the accidental arc to ground. If the ground is of the arcing type, the arc will, under favorable conditions be extinguished, as the energy flowing through the fault is only that necessary to supply the losses in the resonant circuit. If the losses are low, the energy flowing through the fault will be insufficient to support an arc and the voltage of the resonant system is gradually reduced to zero, while the voltage between the former faulty wire and ground gradually rises to normal value.

In a comparison of the various methods of grounding and their effects on the operation of a power system, the solid and the low-resistance grounds assume first and second place in the order of desirability. The distinction however, between these two is slight and choice will be determined by local conditions. Either the Petersen earth coil or the critical-resistance ground will assume third place in the order of desirability as the relative advantages and disadvantages of these two are about equal.

The advantages of the Petersen earth coil system are: first, the suppression of arcing grounds under favorable conditions; second, the reduction of insulator trouble; and third, small earth current when a fault occurs to ground.

The disadvantages are: first high potentials between line and ground due to series resonance; second, maintenance of a series of arcs under unfavorable conditions, that is, resonance and high loss, or large dissonance and either high or low loss; third, difficulty in obtaining selection of the faulty line by means of relay protection; fourth, reduced lightning protection due to the necessity of high settings on arresters; and fifth, increased system insulation due to the shifting of the neutral with abnormals or transients.

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II. Operation.
- Effects of Resonance and Energy Loss. (240 w.)
- Effects of Dissonance and Energy Loss. (150 w.)
- Voltage between Sound Wires and Ground. (120 w.)
- Series Resonant System. (190 w.)
- Maintenance of Resonance. (100 w.)
- Lightning Protection. (220 w.)
- Relay Protection. (360 w.)
- Effect on the Insulation of Systems. (175 w.)

III. Operating Tests. (120 w.)
- The Earth Coil of Variable Inductance. (120 w.)
- Tuning the Earth Coil and Dissonance. (250 w.)
- Grounding and Ungrounding One phase. (1300 w.)

IV. Comparison of Methods of Grounding Neutrals of Systems. (400 w)
- (v) Voltage Stresses. (300 w.)
- (w) Current Stresses. (50 w.)
- (x) Relay Operation. (50 w.)
- (y) Continuity of Service. (175 w.)
- (z) Cost. (100 w.)

V. Conclusions. (330 w.)

THE use of an inductance coil connected between the neutral of a power system and ground is advocated in an article by Prof. W. Petersen of Darmstadt, Germany, in the *Electrotechnische Zeitschrift*, January 2nd and 9th, 1919. This inductance is resonated at the fundamental system frequency with the capacity reactance of the power system to ground. It is claimed that when one wire becomes grounded the current flowing through the fault is of insufficient value to support an arc.

Additional information relative to the operation and limiting features of the earth coil has resulted from investigations and tests made in this country and a comparison made between this and other methods of grounding.

I. Theory

The earth coil is applicable to single-phase and polyphase systems upon which a neutral may be established. For the sake of simplicity, however, the single-phase system will be considered first.

A single-phase transmission system is represented schematically in Fig. 1, involving a generator, *G*,

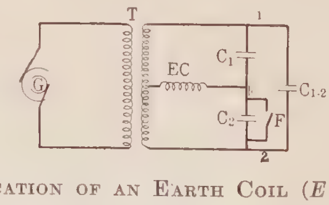


FIG. 1—APPLICATION OF AN EARTH COIL (*E C*) TO A SINGLE-PHASE CIRCUIT

Closing the switch *F* is equivalent to an accidental ground on wire 2 and actually short-circuits its capacitance.

a transformer, *T*, a capacity between wires 1 and 2, $C_{1\text{-}2}$, capacities between wire 1 and ground, and wire 2 and ground, C_1 and C_2 respectively, and an earth coil *E C*. A fault on wire 2 to ground short-circuits the condensers C_2 and the system may then be represented as shown in Fig. 2.

To be presented at the 10th Midwinter Convention of the A. I. E. E., New York, N. Y., February 15-17, 1922.

This diagram (Fig. 2) shows that the charging current for the line capacity C_{1-2} flows through the wires 1 a d 2 as heretofore, but the charging current for the capacity C_1 flows through the earth coil $E\ C$, fault, and wire 1. The exciting current for the earth coil $E\ C$ flows through wire 2, fault, and earth coil $E\ C$, forming with the

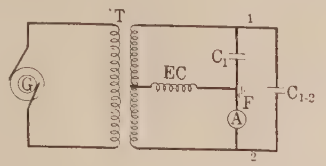


FIG. 2—SIMPLIFICATION OF FIG 1 WHEN WIRE 2 IS GROUNDED

The voltage on the capacitance between wires 1 and 2 remains constant but the voltage between wire 1 and ground has risen from half to full line-to-line voltage.

capacity C_1 a parallel resonant circuit adjusted for resonance at fundamental power frequency. In practise, the currents through the earth coil and the capacity

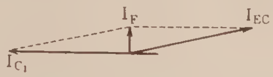


FIG. 3—CURRENT IN THE EARTH COIL ($E\ C$), CURRENT IN THE CAPACITANCE WIRE 1, AND THE RESULTANT CURRENT OF THE TWO (I_F)

C_1 to ground are quite large but the two currents being almost in opposition as shown in Fig. 3, the resultant current, which is the current through the fault, is

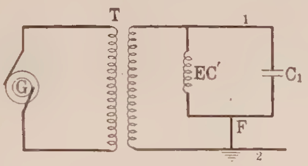


FIG. 4—SIMPLIFIED DIAGRAM OF FIG 2

comparatively small, and is determined by the values of energy losses in the resonant system.

The conditions of resonance of a reactor and condenser

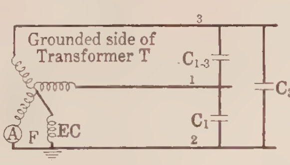


FIG. 5—APPLICATION OF THE EARTH COIL ($E\ C$) TO A THREE-PHASE CIRCUIT, WITH WIRE 2 GROUNDED

in parallel are shown more clearly in Fig. 4 in which the earth coil is replaced by an equivalent reactor, taking the same current and connected across the lines.

A three-phase star-connected system with earth coil is shown in Fig. 5. The operation of this system on the occurrence of a fault to ground is similar to the single phase system shown in Fig. 4 but in this case the earth coil is to be resonated with the sum of the currents through the capacities C_1 and C_3.

The earth coil may be tuned with the line capacities to ground under actual operating conditions by inserting an ammeter as shown in Fig. 2 and with one phase wire grounded adjusting the reactance of the coil for minimum current as shown in Fig. 6.

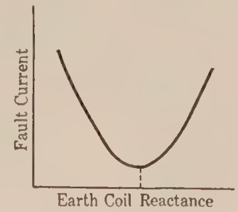


FIG. 6

The lowest part of the curve of current occurs at the value of reactance which gives resonance with the capacitance in parallel.

II. OPERATION

Effects of Resonance and Energy Loss. The most favorable conditions for the proper functioning of the earth coil, that is, the suppression for arcing grounds are perfect resonance and low energy losses in the resonant system. Under these conditions, the voltage across the fault, which is the difference between the supply voltage and the voltage of the resonant system, builds up gradually to the normal voltage to ground. When the current through the fault is interrupted, due to there being insufficient current to support an arc, the two voltages have magnitude and phase relations shown in Fig. 7. The voltage of the resonant system is then gradually reduced to zero by the dissipation of the energy losses and the voltage between the former faulty wire and the ground rises gradually to normal value.

The chief advantages of the Petersen earth coil system are due to the two characteristics, of small fault current,

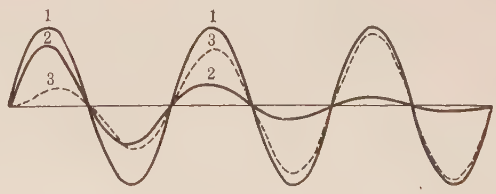


FIG. 7

1. Supply voltage.
2. Resonant voltage.
3. Voltage across the fault.

When the current through the fault is interrupted the voltage across the fault gradually rises and reaches normal value after a few cycles. (See the dotted curve.)

and the gradual rise to normal voltage on the lines after an arc has been extinguished. The earth coil avoids trouble from arcing grounds because it prevents the cumulative action of successive arcs and thus precludes the building up of high voltages, tending to cause serious disturbances.

With perfect resonance, but high loss, the operation

is as described above, except that the fault current is very much larger and may be of sufficient magnitude to maintain an arc, thus preventing a realization of the advantages of the earth coil.

Effects of Dissonance and Energy Loss. The effect of dissonance with either high or low loss is to cause the resonant system to have a natural frequency other than that of the supply, consequently the voltage across the fault may rise to a value slightly less than twice the star voltage in a period of a few cycles, as shown in Fig. 8. This voltage may be even larger than that which occasioned the fault and, as a result,

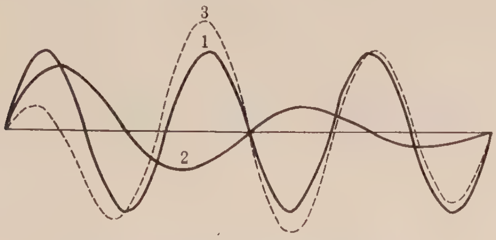


FIG 8—CONDITION OF DISSONANCE

1. Supply voltage.
2. Resonant voltage.
3. Voltage across the fault.

The voltage across the fault (dotted wave) is shown as rising above normal voltage in the second cycle after the arc ceases in the fault.

a series of arcs may be maintained. System oscillations producing a succession of arcs may become cumulative in their effect and produce excessive voltages. The maintenance of such a succession of arcs, causes the transmission line as a whole to vibrate up and down in voltage and may lead to serious trouble.

Both dissonance and energy loss increases the current through the fault and on this account an arc may be maintained. If the arc is maintained the transmission wire or insulation will probably be damaged to such an extent as to put the line out of commission effectively.

Voltage Between Sound Wires and Ground. When the equivalent of a non-arcing ground occurs on one wire, the voltage between the sound wires and ground will rise from Y voltage to line voltage above ground. But when there is a "make and break" through the accidental arc the transient voltage may rise to slightly less than twice line voltage. This high voltage is the result of a redistribution of energy in the resonant system at the instant the fault occurs.

Laboratory experiments made on an artificial line indicated that when a fault occurs, the sound wires will under extreme conditions, rise to 250 per cent or more of normal voltage. With the set-up of apparatus shown in Fig. 9 the application of a fault at the switch y produces the high voltages measured by the spark gap at the sphere gap x. In this respect, the earth coil system operates similarly to a *free neutral system.*

Series Resonant System. The system may also be considered as a series resonant system as shown in Fig. 1 in which current flows through the earth coil, $E\,C$, divides equally in the transformer T, and flows through the two line wires and through their respective capacities C_1 and C_2 to ground. Any voltage induced in series with the series resonant system will produce a current limited only by the losses of the system. The voltage which may appear between the neutral of the system and ground is determined by the impedance of the earth coil and the current flowing through it.

Voltage may be induced in the series resonant circuit by some other transmission line, by lightning discharges, by mutual induction, by unsymmetrical impedance under load, unequal capacities from line to ground, or such abnormal conditions as a single-phase short circuit or an open circuit on one wire. The induced voltage may be only a small percentage of the star voltage, but if the resistance of the system is low, and if resonance occurs, the voltage between one wire and ground may be many times the star value.

For this reason then, if the earth coil is used, special attention should be given to the transmission system to have it well transposed and balanced.

Maintenance of Resonance. The condition necessary for the most successful operation of the Petersen earth coil, that is, resonance and low energy loss, is difficult to obtain and maintain on a network composed of a variable number of feeders operating in parallel. For such cases adjustable reactors are required. Either a main earth coil may be provided with taps, so that the inductance may be adjusted for each change in line capacity, or an individual earth coil may be associated with each feeder, these coils being cut in or out with the feeder. Such complication, requiring a grounded connection on every feeder, appears to be very undesirable, and such installations are contrary to usual American practise.

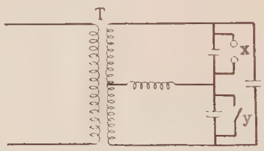


FIG. 9—CONNECTIONS OF AN ARTIFICIAL LINE TESTED IN THE LABORATORY

When a fault was produced at the switch y the voltage across the sphere gap x rose to two and a half times the normal value.

Lightning Protection. The installation of the earth coil necessitates a change in lightning arrester settings for the transmission system. With the grounded neutral system, the lightning arresters are set so as not to discharge for star voltage under wet weather conditions. With the earth coil in service, the protection must either be reduced by setting the arrester higher than line voltage or cutting the arrester out of service when a transmission wire becomes grounded. Neither of these alternatives is desirable. On systems where lightning disturbances are infrequent, the operation of the earth coil, requiring an increase in the setting of the arrester, may not be very detrimental, but in

other regions the change in the lightning arrester setting would be very undesirable. If the earth coil were capable of satisfactory performance for various conditions, its operation would tend to relieve the arrester from interrupting the power arc which follows a lightning discharge.

The introduction of any impedance between the neutral point of a system and ground permits the *neutral to rise to a voltage above ground* during abnormal conditions. Hence the installation of the earth coil would impose greater voltage stresses on the transmission system under abnormal conditions, including lightning disturbances, than would be the case with a solidly grounded neutral.

Relay Protection. The installation of the earth coil in the neutral of a transmission network protected by any modern relay system prevents the automatic isolation of a grounded feeder due to the small differences in magnitudes and phase relations of the resultant currents flowing during the abnormal condition from those flowing under mormal conditions. Devices which give satisfactory indications showing the particular phase grounded are obtainable, but considerable difficulty will be experienced in determining immediately the particular feeder that is accidentally grounded.

An impracticable method of locating the faulty feeder is by an increase in current brought about either by the introduction of sufficient dissonance or by the increase of energy loss to such a value that the fault current will be of sufficient magnitude to operate the relays selectively. Under these two conditions the fault current may support an arc and the principal advantage of the earth coil installation will be lost.

As an alternative suggestion of a solution of the problem, it should be noted that the installation of a critical resistance at the neutral of a relatively small power system will also offer the same possibilities as a Petersen earth coil. The critical resistance at the neutral of a large system has the advantage of permitting sufficient value of current to obtain selective relay operation.

If the fault persists for an appreciable length of time, another method of overcoming the disadvantage of the earth coil is the installation of a relay in series with the earth coil which causes a switch in shunt with the earth coil to close and thereby solidly grounds the neutral of the system. When the earth coil is shunted by the switch, sufficient current for selective relay operation is permitted to flow. This is really a combination of two systems, initially an earth coil system, changing over to a solidly grounded neutral system and, therefore, it has some of the advantages and disadvantages of both. With this arrangement, it is evident that, if an insulator flashes over and the arc persists, the system just described would punish the insulator more than would be the case if a solidly grounded neutral were employed. On the other hand, if the earth coil system interrupts the arc following an insulator flashover, it is evident that the particular insulator would not be punished as much. However the insulators on the other phases would be subjected to higher voltages with the use of the earth coil than would be the case with solidly grounded neutral.

Effect on the Insulation of Systems. The Petersen earth coil system cannot be applied to transmission systems having transformers with graded insulation, due to the fact that when one line becomes grounded, the other lines rise to line potential above ground; nor to systems in which auto-transformers are used, due to the excessive voltages it would impress on low-voltage windings when a fault occurs in the high-tension side. Hence the adoption of the earth coil would materially increase the cost of the higher voltage transmission systems by preventing the possible economy arising from the use of graded insulation on transformers and the use of auto-transformers with a solidly grounded neutral.

The adoption of the earth coil system as compared to a grounded neutral system, would increase the voltage stresses which would be imposed upon transmission line insulators, on cable insulation, and on switching equipment. As a result, either the cost of line insulators and switching equipment would be increased or the factor of safety in insulation would be materially reduced.

III. Operating Tests

Tests were made upon a 26,400-volt, three-phase, 60-cycle network of five lines totalling 59.8 miles, to obtain information relative to the operation of the Petersen earth coil and to collect data indicating the suitability of such an installation for the suppression of arcing grounds.

The charging currents of the systems were measured with various combination of lines as follows:

Lines in Service	Amperes Charging Current
H-112, *V*-126, *L*-142, *G*-111, *B*-132 (All Lines)....	11.2
H-112, *V*-126, *L*-142, .. *B*-132.............	10.5
H-112, *V*-126, .. *G*-111, *B*-132.............	10.6
H-112, *V*-126, *L*-142, *G*-111, ...	5.9
.. *V*-126, *L*-142, *G*-111, *B*-132.............	10.0
H-112, .. *L*-142, *G*-111, *B*-132.............	10.0

The Earth Coil of Variable Inductance. Approximately a 1450-ohm reactance, rated at about 160 kv-a. was required for installation at the neutral of the system to resonate with the capacitance. This value was made up by connecting the high-tension side of a 300-kv-a. transformer (ratio of 13,200/2,400 volts) between the neutral of an 11,500-kv-a. transmission transformer (ratio of 13,200/26,400 volts) and ground. Two 100-kv-a. distribution transformers (ratio of 2400/240-480 volts) were connected to the low-tension side of the 300-kv-a. transformers, and on the low tension side of the two 100-kv-a. transformers a 250-ampere, 5 per cent feeder reactance (1.525 ohm)

was connected. Adjustment of the correct reactance value was obtained both by changing the ratio of transformation and by tapping off only such portion of the reactance coil as needed.

Tuning the Earth Coil and Dissonance. The earth coil was adjusted to resonate at 10.5 amperes, which is the charging current for the electrostatic capacity of four feeders of the network, consisting of the second group of lines in the table above, viz.: *H*-112, *V*-126, *L*-142, and *B*-132. Line *G*-111 was out of service. Leaving the earth coil reactance constant and reconnecting *G*-111 (charging current 11.2 amperes) a condition of +7 per cent dissonance[1] was established. Next, disconnecting *B*-132 a condition of − 44 per cent dissonance was established. In addition to providing convenient operating conditions, these combinations of feeders provided a wide range for tests. Incidentally the weather was hot and dry at the time the earth coil was tuned. There had been no rain for several days and therefore the line leakage was small.

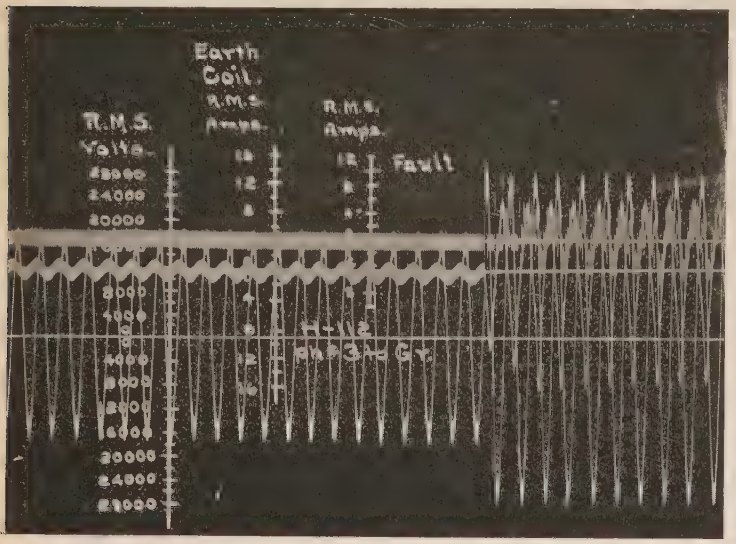


FIG. 10—FILM 13

Reactance of the Earth coil is at resonant value. Phase No. 1 is grounded at the instant shown in the oscillogram of sudden change of currents and voltage. The three records are as follows: The upper record (right scale) measured the current in the fault. This current is shown as a wide zero line until the ground is made on phase 1 when the deflection suddenly rises to a peak value of about 7 amperes.

The middle record (middle scale) measure the current in the earth coil. This current has a peak value of nearly 1.5 amperes (the small thick lined wave) even under normal insulation of the three phases. This current is due to unbalanced conditions of the three phases. When phase 1 is grounded the current in the earth coil rises to a steady state value with an average peak of about 16 amperes.

The lower record (left scale) measures the voltage of a non-grounded phase: that is, phase 3 to ground. When phase 1 is grounded, phase 3 rises from *y* voltage to delta voltage.

The Petersen coil was adjusted for 60-cycle resonance under service conditions by measuring the current through a ground fault applied to No. 1 phase of Line *H*-112 and measuring the current through the coil. A number of progressive changes were made in order that the point of minimum current through the fault indicating resonance, might be determined. The unneutralized or residual current under this condition was 2.7 amperes with 11.9 amperes through the earth coil.

The total energy loss in the system under dry weather conditions, determined by the decrement method, was about 30 kw. of which about 12 kw. occurred in the earth coil. The energy (not voltage) loss in the earth coil might be reduced somewhat for a permanent installation, by making up a specially wound coil, but the loss in the earth coil being the minor fact, the total loss could not be greatly reduced. The effect of wet weather conditions will be to increase the energy losses and this factor can not be controlled.

Tests—Grounding and Ungrounding One Phase. In addition to other tests, oscillograms were taken to show the ability of the earth coil to suppress arcing grounds and to obtain data on the operation of the coil during the transient state.

A fault was placed on phase No. 1 of feeder *H*-112 at the station end, with various combinations of transmission lines in service. Tests were made with resonance and with + 7 per cent and − 44 per cent dissonance. In each of these dissonance tests the shortening of the gap by closing a disconnecting switch caused a steady arc discharge as the blade approached the jaw of the switch. On opening the switch there was no evidence of an arc. These results indicated

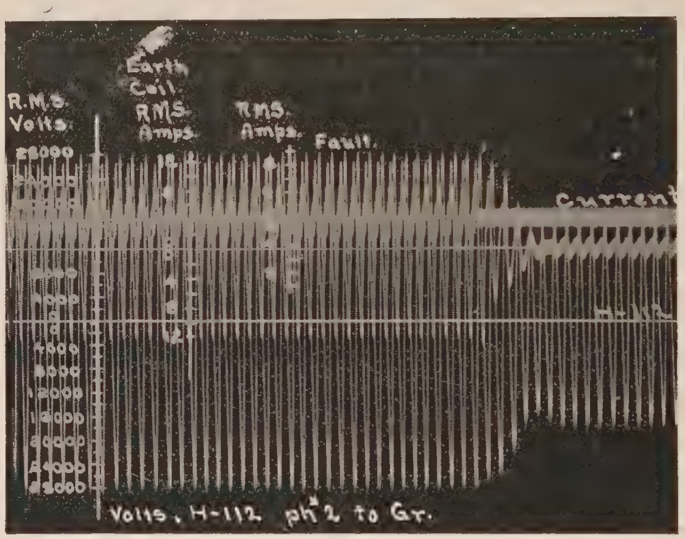


FIG. 11—FILM 15

Reactance of earth coil is at resonant value. The ground on phase 1 is removed at the instant shown in the oscillogram of sudden change of currents and voltage. The three records are as follows:

The upper record (right scale) measures the current in the earth coil. When the switch representing the fault is opened, the current drops from the continuous value it previously had to zero (shown by the wide horizontal line of the upper record).

The middle record (middle scale) measures the current in the earth coil. When the switch representing the fault is opened the current in the earth coil does not drop immediately to zero value as in the case of the current in the fault. The current in the earth coil first rises a little and reduces gradually through three successive cycles to the small value of unbalanced current that is characteristic of the system.

The lower record (left scale) measures the voltage between ground and a non-grounded phase. After the ground is removed from phase 1 this voltage gradually through three cycles reduces to less than *y* value and recovers in two cycles to *y* value.

1. In this article the use of ± *a* per cent dissonance indicates that the charging current was *a* per cent greater or less than that required for resonance.

that, for dry weather condition, considerable variation in the number of lines connected in service was permissible without destroying the effectiveness of the earth coil to suppress the arc.

The oscillograms, for example, film 13, indicated that there was a certain amount of dissymmetry in the three phases of the transmission system which caused current to flow in the circuit composed of the transmission lines and the capacity to ground, returning to the lines through the earth coil and the step-up transformers. The magnitude of this circulating current was determined by the change in magnitude of load current, but was, however, quite small—about one ampere.

The voltages of the different phases to earth changed almost instantly with the application or removal of the fault. This result was to be expected as the change of voltages takes place as rapidly as the line capacity charges or discharges.

At resonance, and during the steady state condition, the current through the fault (film 15) appeared quite peaked, having a maximum value of 4.5 amperes. The corresponding maximum value of current through the earth coil was 17 amperes. On closing the fault, the current built up through the earth coil in from 3 to 4 cycles. On opening the fault, the current through the fault dropped to zero immediately and the voltage between phase 3 and ground became stable in 4 to 5 cycles. There was a noticeable overcharge during the transient which occurred on opening the fault as shown by the voltage, phase 3 to ground, in films 15 and 16.

During the transient which occurred when the fault was closed with a condition of +7 per cent dissonance, the current through the fault reached a maximum value of 18 amperes, and the current through the earth coil, a maximum of 70 amperes. The transient lasted for about 4 cycles, during which the current through the fault reduced to a steady state maximum value of 4.5 amperes and that through the earth coil to a maximum value of 17 amperes.

On closing the fault with a condition of −44 per cent dissonance, the current through the fault reached a maximum value of about 45 amperes and through the earth coil a maximum of 100 amperes. After a transient lasting from 12 to 15 cycles, the current reduced to a steady state values of 7 amperes maximum through the fault and 16 amperes maximum through the earth coil.

These tests showed that for the steady state the current through the fault and the current through the earth coil approached the same steady value, and that the transient current on opening the fault lasted the same number of cycles. However, on making the fault, the character of the transient current depended upon the particular instant at which the switch was closed. During the transient conditions there appeared to be an even harmonic in the earth coil current. This effect of an even harmonic was probably due to the unidirectional flow of energy, to re-establish balanced conditions, which caused the transformer to become saturated. Hence during the transient condition the peaking of the current wave during one half of the cycle and the flattening of the wave during the other half of the cycle were to be expected from the particular conditions that existed for this test. In addition, a path for the return of negative current from a local street railway was provided by the fault, the current flowing through the fault, the transmission wire, the transformer, and the earth coil to ground. This flow

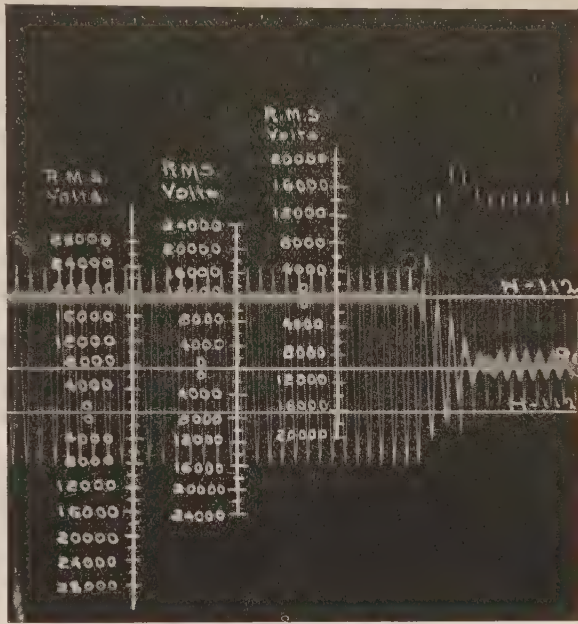


FIG. 12—FILM 16

Reactance of Earth coil adjusted to resonant value. As before, the ground on phase 1 is removed at the instant shown in the oscillogram of sudden change in the voltages. This oscillogram shows three voltages (no currents). The records are as follows:

The upper record (right scale) is the voltage of phase 1 to ground. This voltage is shown as a wide zero line until the switch representing the fault is opened when it rises in four successive cycles to a value slightly greater than its normal y value oscillates to less than normal and then returns to normal.

The middle record (middle scale) is the voltage across the earth coil, that is to say from neutral to ground. This voltage drops gradually in four successive cycles to the small constant value which is characteristic of the unbalanced system.

The lower record is too dim to reproduce. It is the voltage of the non-grounded phase 3 to ground. In four successive cycles it gradually reduced from delta value to y value.

of direct current would also tend to saturate the transformer and produce even harmonics.

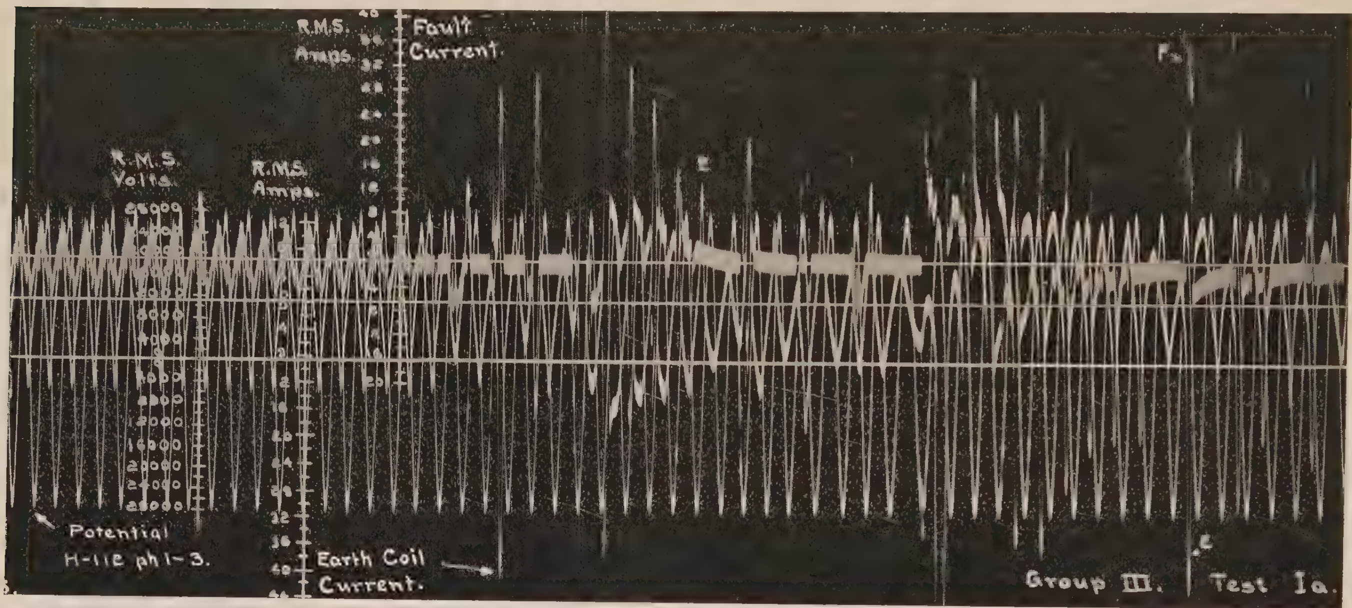
Tests were also made to determine the possibility of maintaining a continuous series of arcs by moving the fault disconnecting switch back and forth within arcing distance. The test was made with +7 per cent dissonance, and with wet weather condition, the air being very moist and the transmission system having been thoroughly soaked by a heavy rain a few hours before the tests.

Under the above conditions a power arc was maintained. The arc was approximately two inches long and several inches broad, and was of a yellow color. The arc was noisy and appeared to the eye to be fluc-

tuating, that is, forming a continual series of arcs. The effect of the arc was to cause the blade and jaw of the disconnecting switch to become slightly pitted at various points.

An oscillogram of this arcing condition, film 25, value of voltage between neutral and ground was about 1.3 times normal.

There appeared to be a certain regularity as to the period at which the arc was interrupted. This average value was from 1.8 to 2 cycles. To explain this uni-



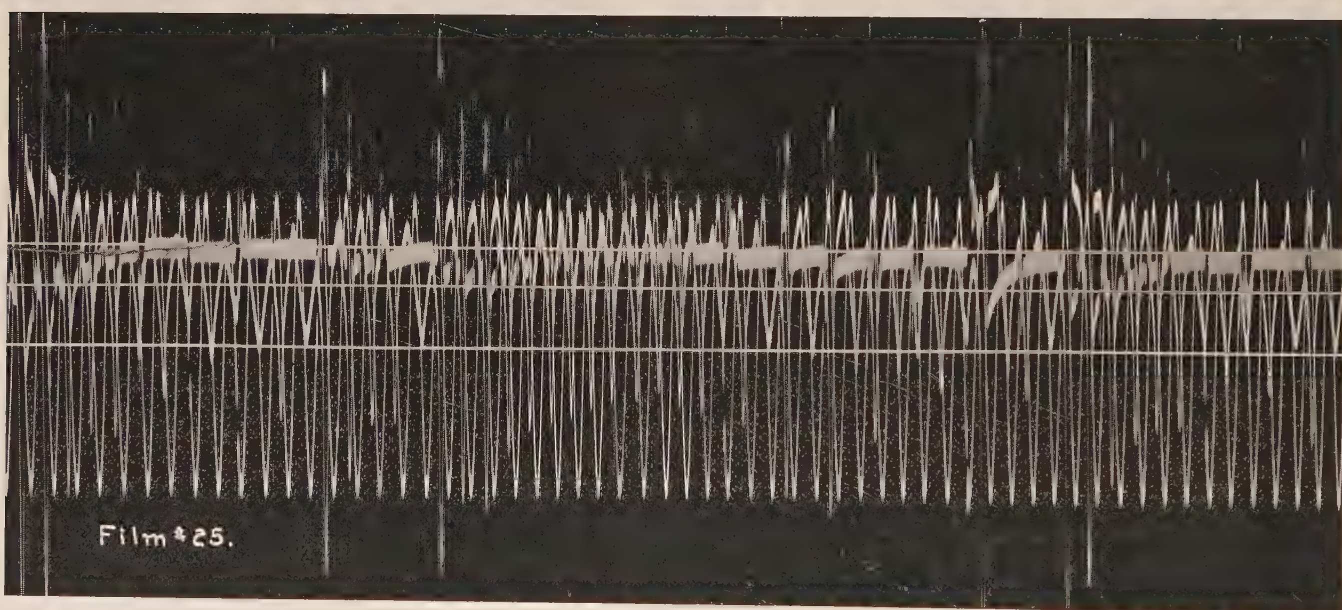


Fig. 13—Film 25

Earth coil not tuned to exact resonance. Dissonance plus 7 per cent. After a severe rain storm an arcing ground was established on phase 1. Again the upper record is the current at the fault, the middle record is the current in the earth coil, and the lower record the voltage to ground of a non-grounded phase.

The oscillogram starts with the condition of metallic ground showing an alternating current wave to ground. This wave is ragged with harmonics (probably 3rd, 5th and 7th). When the switch representing the fault is opened to an arcing position both the current in the arc to ground and the current in the earth coil made many sudden large changes in value. There is great irregularity due to the various instants in the cycle that the arc is extinguished and again established. The current in the arcing ground shows now and then a gradual adjustment toward zero. This was described in the text.

The current in the earth coil shows dangerously high values which carry the deflecteous far off the edge of the film. The most severe current rushes are too dim on the photograph to reproduce (one of these large deflecteous is scratched in).

while rather difficult to follow, brought out a few points of interest. The maximum value of the current through the fault was from 80 to 100 amperes; the maximum value of the current through the earth coil was probably in excess of 70 amperes. The magnitude of the current through the earth coil indicated that the maximum

formity of the re-establishment of the arc, the theory of beats caused by the fundamental frequency and the natural frequency of the oscillating system, has been put forth. On this basis the estimated dissonance was found to be from 6 to 7 per cent. When the fault was applied the two systems vibrated at the supply

frequency and the phase relation between these two systems was such as to cause negligible voltage across the disconnecting switch. When the fault was removed the two systems drifted apart causing the voltage across the disconnecting switch to reach a maximum value in about two cycles. The voltage caused by the oscillating system consisting of the earth coil and line capacities was gradually reduced to zero by the energy losses in this circuit. Hence, the most probable condition for the re-establishment of the arc occurred within a number of cycles corresponding to one half of the difference between the resonant frequency and the supply frequency. The resonant frequency obtained from the above considerations checked well with the increased line capacity.

These tests showed a peculiar wave shape of the residual and of earth-coil currents. This current of the earth coil was shown as a heavy wide line, which curved at a relatively slow rate to the zero value. Apparently this curve was due to the snapping out of the arc at an instant when energy was left in either of two forms, namely, a direct charge stored in the system or electromagnetic energy stored in the current transformer. This stored energy caused a current to flow until the energy was entirely converted into $I^2 R$ loss. Hence, it appeared that the earth coil did not dissipate direct charges entirely, and therefore, did not operate in a way to remove completely the cause of arcing grounds. Reference to film 25 shows that the maximum current through the earth coil, and therefore the maximum voltage between the neutral and ground was preceded by a series of arcs occurring at uniform intervals, indicating that the earth coil system under certain conditions permits system oscillations which are cumulative and produce voltages between neutral and ground which may reach excessive values.

In connection with film 25, it should be noted that with the exception of the weather, the conditions with only 7 per cent dissonance were favorable to the operation of the earth coil. There was no doubt but that the chances for obtaining an arcing ground would have been much greater if line *B*-132 had been cut out of service. The effect of the + 7 per cent dissonance was to increase the effective condenser capacity which probably was somewhat reduced in effect by leakage resistance. During the tests of the arcing condition, the lightning arresters were in service and discharged frequently.

IV. Comparison of Methods of Grounding Neutrals of Systems

Five methods of grounding the neutral are considered and an order of preference given for each from the view points of voltage stresses, current stresses, relay operation, continuity of service and cost. This arrangement is designed to give a clear conception of the status of the earth coil with respect to other methods of grounding and a comprehensive view of the relative advantages of the different methods.

It should be understood that a general comparison of this kind cannot be of a definite and precise character. There are many factors which must be considered and sharp distinctions cannot be made in the analysis. All that is attempted here is to give a general idea based upon a broad classification of the important items that require consideration.

For the purpose of this article, the five methods of grounding the neutral are defined as follows:

v. *Dead Ground.* The neutral connected directly to the grounded earth plate without the installation of reistance or reactance coils.

w. *Low Resistance Ground.* A ground connection to the neutral having a resistor of the order of two to four ohms permanently installed between the neutral and ground plate.

x. *Critical Resistance Ground.* A ground connection arranged as in the preceding paragraph *w*, but of the critical value of resistance necessary to damp out the natural oscillation of the system. In general, this will be a high resistance compared to two to four ohms.

y. *Petersen Earth Coil.* A ground connection to the neutral through a reactor, which takes the place of the resistor of the two previous paragraphs the reactor being tuned for resonance at fundamental system frequency with the capacity of the system to ground.

z. *Infinite Resistance from Neutral to Ground.* This is the ungrounded or free neutral system.

Effect on	Order of Preference				
	1	2	3	4	5
A—Voltage Stresses					
(a) At normal frequency	v	w	x, y, z		
(b) Due to arcing grounds	x, y	v, w	z		
(c) Due to lightning	v	w, x	y, z		
B—Current Stress	z	x, y	w	v	
C—Relay Operation	v	w	x, y, z		
D—Continuity of Service	v	w	x	y	z
E—Cost					
(a) Insulation of power system	v	w	x, y	z	
(b) Grounding devices	z	v	x	w	y

A—Voltage Stresses.

(*a*) *At normal frequency* the dead ground limits the voltage stress which may occur to a constant maximum value of approximately 50 per cent of that which may occur in any other form of ground connection. With the low resistance ground, the voltage stress across transformers may be something less than line voltage.

(*b*) *Due to arcing grounds.* From a technical standpoint the critical resistance and the earth coil under the favorable conditions assumed in the table of comparison, seem to be the most desirable for the suppression of arcing grounds. Under unfavorable conditions the earth coil does not deserve first choice because of the possibility of producing excessive voltages due to the cumulative effects of a series of arcs. However, experience shows that most any system of grounding

is found to be sufficient to reduce the troubles arising from arcing grounds. From a practical operating point of view, many companies prefer to ground the neutral solidly or dead and isolate the feeder on which the ground occurs.

(*c*) *Due to lightning.* Three factors enter into the question of lightning protection. The installation of any impedance between the neutral of the system and ground tends to place additional voltage stresses on transformers and other apparatus. From this standpoint a dead grounded system is to be preferred and the earth coil and ungrounded system are the least to be desired. A second factor is the effect of the installation of a critical resistance which tends to damp out the natural oscillations. A third factor is the adjustment of lightning arresters. With the dead grounded system, the arrester may be adjusted approximately to star potential, whereas with the other methods, it is necessary to adjust for practically line potential.

B—Current Stresses.

The current stresses on apparatus due to currents flowing to ground through a fault are obviously zero with the ungrounded system and a maximum with the dead ground. With a grounding system permitting adequate relay protection, line to ground faults should not develop into line to line faults, hence the use of an impedance in the neutral would reduce the duty on breakers.

C—Relay Operation.

The reliability of relay operation is dependent upon the value and uniformity of the characteristics utilized to select the faulty lines. The dead ground is therefore to be preferred, as the variations in the resistance of the fault may limit the current flow to such values as to give incorrect relay operation if a resistance or other current limiting device is installed.

D—Continuity of Service.

In any power system the essentials necessary for the provision of continuous service are: first, the prevention or reduction of disturbances which may result in failure of apparatus, lines or equipment, and second, the isolation of apparatus, lines or equipment in the event of failure.

Since the means of prevention or reduction of disturbances on power systems has not developed to the extent that relay protection has been developed, a majority of the power companies prefer to rely on the latter method. The dead ground is, therefore, to be preferred which permits the utilization of full current values for selective relay operation. From a purely operating standpoint, however, some difficulty is experienced in holding synchronous machines in step after a fault has been cleared on a dead grounded system. Consequently a low resistance is generally installed in the neutral. The introduction of any impedance in the neutral connection tends to limit the distortion of the voltage triangle in case of a ground on one wire and thus to increase the probability of synchronous machines staying in step.

E—Cost.

(*a*) *Insulation.* Theoretically, there will be a difference in the cost of insulating a power system in favor of the dead ground. Advantage has not been taken of this fact, except for high-voltage systems; most power companies preferring to employ the additional factor of safety.

(*b*) *Grounding Devices.* Of course the ungrounded system is the cheapest in this respect and the dead ground without the installation of limiting devices is the next preference, the installation of the earth coil being most undesirable, particularly if it is necessary to employ reactors associated with each feeder.

V. Conclusions

The advantages of the Petersen earth coil system are: First, the elimination of arcing grounds under favorable conditions; second, the reduction of insulator trouble; and third, small earth current when a fault occurs to ground.

The disadvantages are: First, high potentials between line and ground due to series resonance; second, maintenance of a series of arcs under unfavorable conditions, that is, resonance and high loss, or large dissonance and either high or low loss; third, difficulty in obtaining selection of the faulty line by means of relay protection; fourth, reduced lightning protection due to the necessity of high settings on arresters; and fifth, increased system insulation due to the shifting of the neutral with abnormals or transients.

An analysis of the table giving an order of preference, results in the following arrangement of the different methods of grounding from the viewpoint of desirability: First, dead ground; second, low-resistance ground; and third, critical-resistance ground or the Petersen coil. The distinction however between dead ground and low-resistance ground is very slight and choice will be determined by local conditions. Either of these is generally preferable to the critical resistance or Petersen earth coil. An installation of an earth coil on a free neutral system would probably result in a reduction in interruptions to service. An installation of an earth coil on a dead grounded system would probably show no improvement in service and under most circumstances would introduce complications. In this connection, it is pointed out that reduction in interruptions are not significant, if made on the basis of a change from free neutral to earth coil, but merely prove that a grounded system is better than an ungrounded neutral system.

Numerous technical difficulties with the earth coil have been pointed out and it is interesting to find that some of these points, such as high potential due to series resonance, have given rise to serious interruptions in some European installations.

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

INFLUENCE OF ILLUMINATION LEVELS UPON SPEED OF VISION INVESTIGATED

Dr. P. W. Cobb, of the Nela Research Laboratory, has just made public a preliminary report upon some experiments which he undertook for the purpose of obtaining a fundamental idea of the influence of levels of illumination upon the speed of vision, and ultimately, if possible, of determining the exact relation existing between these two things. While these experiments make certain assumptions which have not yet been experimentally tested and technical application of the results are therefore not warranted at the present time, Dr. Cobb's investigations clearly show that there is a general relation between speed of vision and illumination intensities, and indicate that this relation is different for different individuals. The following is an abstract of Dr. Cobb's report on these experiments.

In reading an ordinary line of print, the eyes fix momentarily upon a limited number of points, perhaps 2 to 7 in a line, and the material lying between these successive fixation points is sensed during the brief fixational pauses. This fact has led to the conclusions that the stimulation of the eye which plays its part in all ordinary work is usually momentary and is ordinarily incident upon parts of the retina other than its center. It was this consideration which led to the choice of the method used in these experiments.

An illuminated white screen (*S*, Fig. 1) with circular opening *O*, is viewed by the observer *X* at a distance of six meters. The opening is made to vanish by an illuminated screen back of *S* and photometrically balanced with it. An opaque object placed back of the opening then darkens it, so that it appears as a black dot. The observer fixes upon a marked point *P*, two degrees to the left of the opening, so that the latter is seen two degrees eccentrically to his right. A set of interchangeable blinds of different widths which fall freely under the influence of gravity just behind

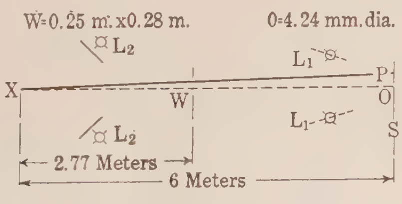


Fig. 1—Diagram Showing Arrangement of Apparatus Used

the screen *S* is used to vary and measure the duration of the dot. The observer views these durations in a series of readings made under different levels of illumination or, more accurately stated, different screen-brightnesses—in each case, the quantity measured is the minimum duration of the dot necessary for its perception.

The observer sat in a second room and viewed the screen through an opening in the wall. The wall was illuminated by two Mazda C lamps L^2, as shown; lamps of different sizes were employed to obtain the brightnesses charted in Fig. 2. The lamps near the screen L^1, were mounted on tracks so that the brightness

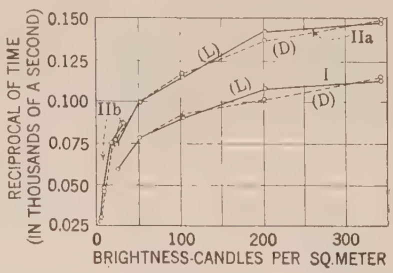


Fig. 2—Curves Indicating Relation of Levels of Illumination to Speed of Vision, as Determined (I) for Seven Observers, and (II) for the Three Most Consistent Observers of the Seven. (One Candle per Square Meter is Equivalent to about ⅓ Foot-Candle on a White Surface)

of the screen could be balanced with that of the wall. Special care was then taken to maintain a perfect photometric balance between the screen *S* and the opening *O* at its center under the different screen-brightnesses obtained.

One set of measurements was made with seven observers, with the light conditions as described (curves *L*, Fig. 2); another set was made with the room in which the observers sat, darkened (curves *D*, Fig. 2). In the latter case the observers could see only the major portion of the screen, marked out by the dark margins of the wall opening. Reference to the two curves show there was very little difference noted in the quickness of impression when the room was darkened. It will be noticed that, except at one point, the *L* and *D* results are practically coincident. The difference between curves *L* and *D* at this point, when considered in connection with its probable error, appears to be of such magnitude as might be the result of chance as often as once in about twelve times; in other words, the difference can hardly be considered significant. Curve *IIa* was plotted from the readings of the three observers who gave the most consistent results in the first set of measurements. Results *II b* for a range of brightness extending to a much lower level were obtained by using these same three observers. It is apparent that a certain definite relation holds true for these three observers at least, from the lowest to the highest values of screen-brightnesses. The curves indicate a rapid increase in the quickness of impression as the illumination is increased. They also seem to show that the increase in the speed of

vision is relatively slow as we get into the higher illuminations.

Dr. Cobb points out that the lengths of time required for visual impression in his experiments (7 to 34 thousandths of a second) are considerably less than the time of the ordinary fixational pauses of the eyes in reading, which have been found to be from 100 to 250 thousandths of a second, and that it might thus appear that the difference between the extreme (7-34) is, after all, not of importance. He explains, however, that the objects observed in his tests are absolutely black, seen against a surface of stated brightness. If the size of the hole in the screen, or the contrast mentioned, or both, were to be reduced, and increase in the time of seeing would undoubtedly result, and it might then become of the same order of magnitude as the typical fixation pause. Also, under the experimental conditions used, the stimulus always arose out of an unbroken white surface. This is, of course, not ordinarily the case in eye-work, where it is usual that the stimulation resulting from one fixation falls upon a retina in which images due to the last stimulation (possibly also stimulations prior to that), although rapidly dying out, are still enough alive to delay the clearing up of the present image. This factor has been shown by another investigator to be an important one. The present work has, for the purpose of arriving at the fundamental fact, aimed to eliminate it, as a factor difficult to control and to standardize, on the assumption that what is found to hold true of the rapidity of vision under the conditions actually used will, in general, be found to vary in a similar way in the presence of disturbing factors if these latter are kept constant.

In this connection, it is to be stated that work is now being planned which has for its aim the inclusion of the factor spoken of in the last paragraph; namely, the disturbing effect of the dying-out impression due to a previous exposure and the variations in this as a function of illumination and of distribution. Plans have been worked out to the point of showing clearly that such an investigation is technically feasible, and it is expected that the results will be available before long.

ELECTRIC SIGN LIGHTING

That a new era in sign lighting is on in earnest is evidenced by the rapidly increasing number of new, bigger, and brighter electric signs in all parts of the country. There is hardly a city or town of any size in which the residents have not experienced real thrills from gazing upon one or more recently-installed, attractive, interest-compelling electric signs. Whether located in the world-famous white-light district of Broadway, or over the door of the general merchandise store on Main Street in a small town, the brighter electric signs shine forth at night and burn their glowing messages into the minds of all passers-by with great effectiveness.

Up to about a year and a half ago, the vast majority of electric signs in this country employed 2½- 5- and 10-watt sign lamps. In the short period of a year and a half, however, many of the signs in the downtown districts in cities of all sizes and in a great many towns have been entirely re-equipped with higher-wattage lamps, so that today these signs are filled with 25-, 50-, 75- and, in a few instances, 100-watt lamps, depending upon the brightness of the background and surrounding areas.

A dominant factor in this transformation of these signs has been the work carried on in this field by sign and lamp manufacturers in various sections of the country, who have pointed out to sign users the numerous advantages of high intensity sign lighting, with

Fig. 1—Many Different Types of Electric Signs are Employed in this Theater District

the result that a large number of first-class signs may now be found in almost every city and town, and the number is constantly increasing.

Fig. 1 shows the large number of electric signs used in the theater district of one large city. This photograph is especially interesting from the standpoint of the different types of signs illustrated. It will be noted that the translucent letter sign on the extreme right is clear and sharp against its dark background, which is characteristic of this type of sign. For signs with letters less than 16 inches in height, a very much smoother and more finished appearance is obtained with translucent-letters than with exposed lamps. Another advantage of the translucent letter signs is that they present a good appearance both during the day and at night. The power cost of these signs is less than that of exposed lamp signs, not because they are equally effective when less bright, but because they use a smaller number of larger and, therefore, more efficient light units to get the same, or an even greater average brightness.

On the letters of the theater sign in the center of the photograph, 50-watt white Mazda lamps are used. In parallel with these 50-watt lamps, a circuit of 10-watt lamps outlines the letters. The two circuits are provided to make it possible to have two distinct effects for proper occasions. The other theater signs and their marquise are equipped with 75-watt daylight lamps, which give them a high degree of brilliancy. The marquise of the Allen Theater is rendered especially striking and attractive by the use of 75-watt diffusing bulb lamps. These installations are typical of those now found in use at all our progressive theatres.

The Cadillac sign in the distance is an extremely effective electric sign; from every standpoint—characteristic design, location, use of proper lamps, and maintenance, it stands out as a model in electrical advertising. For the past six years this sign was equipped with one thousand 10-watt lamps. As a result of inadequate maintenance, and especially after the installation of a

Fig. 2—This Combination of Electric Sign and Outline Lighting gives a Striking, Distinctly Pleasing Effect

white way street lighting system a few years ago and the more recent development of this theatre district, this sign lost most of its attractive power. Recently the sign was repainted, rewired, and equipped with 25-watt blue mazda B sign lamps, and once more it stands out brightly and is just as effective as it formerly was.

An unusual and very striking example of exterior electrical display is seen in the illustration Fig. 2, of the recently opened Chicago Theater in Chicago. The sign is seventy-four feet from top to bottom, seventeen feet in width and contains 2,874 sockets. The letters of the sign are equipped with 75-watt lamps and 25-watt lamps are used in the border. Equipped with a very attractive flashing schemes, and used, as it is, in connection with the imposing outlined figure of the theater itself, this sign is without question the most effective theater sign in operation at the present time.

HIGHER ILLUMINATION STANDARDS ADVOCATED AS AID TO DEFECTIVE VISION

The report of the Committee on Elimination of Waste in Industry of the American Engineering Council on "Accidents Due to Eye Defects" contains some very interesting observations regarding the prevalence of defective vision as found in the industries today. It stresses the importance of correcting subnormal vision among employees, insisting that excess eye fatigue results in conditions which must produce loss, due to lowering the quantity and quality of whatever is produced. Subnormal vision was found to be of great frequency. One investigation showed that out of 2,906 garment workers only 743 or a little over 25 per cent had normal vision in both eyes, 17 per cent having normal vision in one eye with the other eye defective. The highest percentage of defective vision was in the class of workers who made the greatest use of their eyes.

An examination of more than 10,000 employees in factories and commercial houses found 53 per cent with uncorrected faulty vision. Of 675 employees in a typewriter company, 58 per cent were found to be in need of correction by glasses. Of the rejections of the National Army, 21.7 per cent were because of eye trouble. An examination of the vision of 3,000 employees in a paper box factory in Brooklyn, N. Y., showed that the percentage of normal was only 28. The report continues:

"As in the correcting of other factors of occupational hygiene, standards have been set; so, after further study, visual acuity standards will have to be determined for each grade of workers and readjustments made, with alterations in our methods of testing acuity to suit conditions, until these standards give us the necessary minimum for each kind of work. As examinations are made at present any set level would exclude workers shown by practise to be very efficient producers.

"Many subnormal eyes will work well even for fairly trying work if conditions are good. Therefore, it is first of all urgent to bring the working condition up to the best, on the basis now understood.

"Even the most superficial survey of lighting conditions reveals that in the majority of plants there is much improvement possible, in spite of the actual increase in production quantity and quality when poor illumination is corrected to standards now considered satisfactory. There seems to be no question of loss due to faulty lighting conditions."

One estimate, the report stated, placed the loss due to faulty lighting conditions in this country as above the entire cost of artificial illumination. In 446 industrial plants investigated only 8.7 per cent were found to be in excellent condition. The other ratings were: Good, 32 per cent; fair, 29.1 per cent; poor, 18.8 per cent; very poor, 3.5 per cent; partly good, partly poor, 7.8 per cent.

Electric Power Application to Passenger and Freight Elevators

BY HARRISON P. REED
Fellow, A. I. E. E.
Cutler-Hammer Manufacturing Co., Milwaukee, Wis.

(*Concluded from page 67 of the January Journal*)

IV—ELEVATOR CONTROLLERS

THE elevator controller is one of the most important and at the same time perhaps the most complicated part of the equipment as it provides many of the safety features. The smooth operation of the elevator car is largely dependent upon its functioning, and the design affects the power consumption to a marked degree. Considerable economy can be obtained by selecting the best type for each particular application.

Characteristics

Among the more important characteristics of the control are safety and reliability, although the motor selected should have characteristics that render it inherently safe for elevator operation. The connections to the controller must permit stopping the car at any time under any conditions of load; it should automatically stop upon the release of the car switch handle by the operator. The elevator car must be stopped automatically at each limit of travel to prevent it from traveling into the pit at the bottom or sheave beams at the top of the hoistway. The question of safety is associated with that of reliability. Even if the scheme of control is essentially safe, its proper functioning depends upon the apparatus being reliable.

Controllers must be designed and built to withstand frequent severe operation; one half a million operations a year, partly at least with inexperienced operators who do a great deal of "inching" for landings, not being unusual. Frequent plugging is common, with resultant high currents to be commutated. Also the location of elevator machinery is not conducive to regular inspection, and frequently maintenance is left to the janitor of a building who ordinarily knows little about electrical apparatus and its care.

Elevators are installed in buildings for the purpose of carrying passengers between the ground floor and the upper floors. Many buildings are so tall that it would be a distinct hardship and often an impossibility for the tenants to walk up and down stairs. It is, therefore, necessary to have the elevators in operating condition at all times. In the event of fire or accident it is important that they should function properly to remove the tenants from the upper floors of the building.

Frequently the elevator equipment is located above the hoistway or adjacent to it, so that it is essential to have the controller quiet; otherwise it may disturb the persons who occupy the upper floors.

All unnecessary complications should be eliminated from the controller and all essential adjustments should be readily understood and easily made. After being adjusted the parts should remain fixed under normal operating conditions.

The controller should be neat in appearance and all working parts readily accessible for inspection and repairs. It should be so located as to provide ample working space around it, and sufficient illumination should be provided to facilitate inspecting and repairing this apparatus.

Functions

The elevator controller performs a number of different functions, among the most important of which are the following:

To start the motor and accelerate it to full speed in either the up or the down direction, and to stop it at the will of the operator.

The starting and the stopping of the motor is performed by switches which must make and break the electric circuit. These switches are subject to considerable burning and should be of such design as to withstand this action with infrequent repairs and renewal of parts. The smooth acceleration and retardation of the motor are most important, and usually present the greatest difficulties in the design of the controller. Under different conditions of loading, the motor may act either as a motor or as a generator; therefore the usual methods of accelerating and retarding with a positive load may not give smooth operation when the load is negative. For example; when resistance is inserted in the armature circuit of a d-c. motor under a positive load, the speed of the motor decreases in proportion to the resistance which is inserted. If, on the other hand the motor has a negative load and is operating as a generator, the more resistance inserted in the armature circuit, the faster will be the motor speed. It can be readily seen, therefore, that the ordinary methods of control are not suitable for elevator service. The same remarks apply to a slip-ring induction motor with resistors in the secondary circuit.

To control the speed of the motor at the will of the operator.

The various methods of speed control will be discussed under a separate heading. It is necessary for the control to provide for one or more reduced operating speeds in order to make a satisfactory landing, particularly where the car speed is high. These low speeds should be positive so that they are available

when the motor is operating as a generator as well as under positive load.

To stop the elevator at each limit of travel.

The elevator car travels in a hoistway which is limited at the bottom by a pit and at the top by the beams which support the sheaves and often the winding machinery.

Low-speed elevators can be readily stopped at the top and bottom landings without a preliminary slow-down device, but the higher-speed passenger elevators must be slowed down before the terminal landings are reached in order to make a successful stop. This can be better understood if we consider that the car may be approaching the bottom landing in one case with no-load and in the other case with the maximum load. If the car operates at a speed of 400 or 500 ft. per min. the loaded car will drift considerably farther than the empty car when the controller disconnects the motor from the line and applies the brake. The terminal stops must be so adjusted that the car will reach the bottom landing with a light load. It will, therefore, drift considerably beyond this landing with the maximum load. If the controller provides means for reducing the speed of the car to 50 or 100 ft. per min. before the final stop is made the difference in drift between no-load and full-load will be very small and a satisfactory stop can be made.

To provide additional means for disconnecting the motor from the line and applying the brake in case of overtravel.

The car is stopped at either limit of travel by the regular slow-down and stopping device, but should this device become inoperative, additional means are provided for positively disconnecting the motor from the line and applying the brake in case the car travels beyond its ordinary limits. This latter means usually consists of hoistway limit switches so arranged that the car will open them and stop if it travels beyond its usual limits.

To provide a brake which will positively stop the car and hold it securely at the landing.

Two forms of brakes are used. One is a mechanical brake which is applied by a spring and released by a magnet. This brake is set when the magnet coil is disconnected; it is used for making the final stop and holding the load. The other is the dynamic brake which is used on direct-current machines to assist the magnet brake in stopping the machine. This is obtained by connecting the terminals of a d-c. motor to a resistor, the moving load driving the motor as a generator. By changing the resistance in the armature circuit the retarding torque can be adjusted to suit existing conditions. The satisfactory stopping of the car depends upon the proper adjustment of these two methods of braking.

The controller should govern the motor in an economical manner. The degree of economy will differ for each type of equipment. The current which passes through the resistor units represents a direct loss of energy; therefore the longer this resistance is in circuit, and the more current that passes through it, the less the efficiency of the elevator.

Methods of Operation

A controller may be operated in several ways:

Hand Rope and Lever Control. This consists of a rope which runs the full length of the hoistway in the form of a loop. (Fig. 7 shows the electrical equipment). One half of this loop passes through the elevator car. While the car is in operation this rope is stationary. In order to start, the operator pulls on the rope. This moves the controller and connects the motor to the line for the proper direction of rotation. When the desired landing is reached the operator takes hold of the rope so that the movement of the car pulls the rope in the opposite direction and brings the car to rest. This method of operating elevators is used for low-speed freight machines. A lever or hand-wheel may be used for manipulating this rope instead of having the operator pull on the rope directly. Attachments of this kind enable the operator to govern the controller at higher car speeds, but they are rather cumbersome and not as desirable as full electric control.

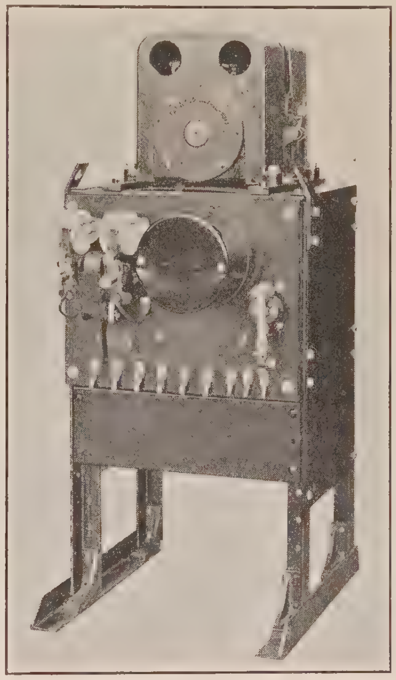


FIG. 7—SELF-CONTAINED A-C. SEMI-MAGNET ELEVATOR CONTROLLER

With phase failure, phase reversal and low-voltage protection.

Car Switch Control. This method consists of locating a master switch in the car. (Figs. 8 and 9 show typical control panels.) The movement of the master switch handle to either side causes the car to travel in the direction desired. The connections are usually made so that the movement of the handle toward the door or front of the car causes a downward motion and a

movement in the reverse direction an upward motion. The switch is arranged with a spring for centering the handle in case the operator releases it, thus bringing the car to rest. The handle is provided with a latch for holding it firmly in the "off" position to prevent accidental starting of the car.

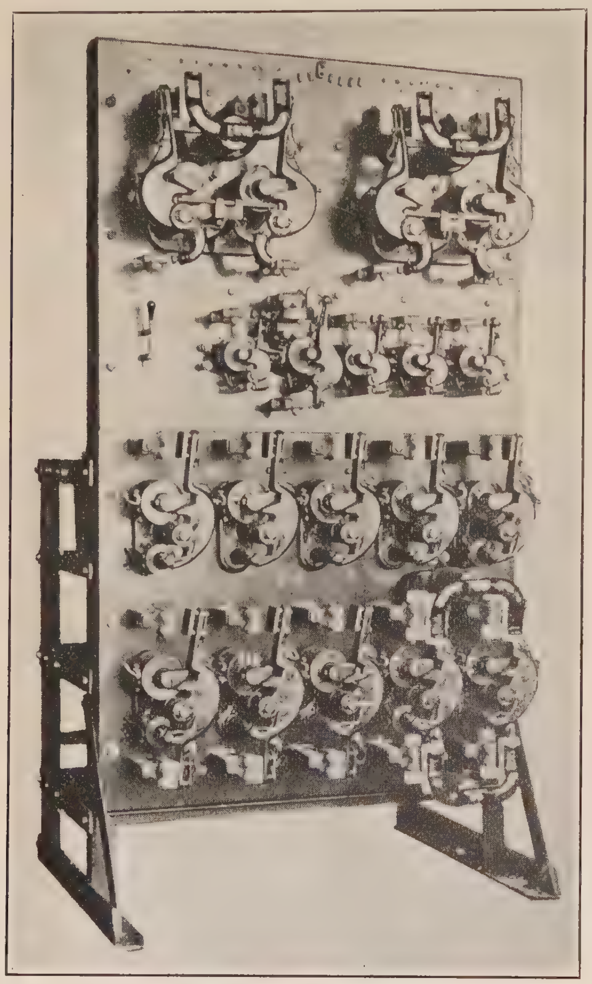


Fig. 8—Full-Magnet D-C. Elevator Controller

This master switch is connected by wires with contactors on the control panel and operates the elevator by energizing the magnets of these contactors. The acceleration of the car is automatic so that the car switch is used only to determine the direction of travel and to select the proper operating speed.

Push Button Control. This method of controlling the car provides for automatically stopping it at the desired landing. (Fig. 10 shows a typical control panel.) It has a particular field of application in apartment houses, small hotels, stores, clubs, etc. where the service does not warrant the expense of a regular operator. The control itself is inherently more complicated than other types and therefore is not quite as reliable. It is a time and power waster because so many trips are made with light loads and without regard to floor demands.

A push button is located near each landing door. When a button is depressed momentarily, the proper connections are set up in the controller to move the car to that particular landing and to automatically stop it when it reaches the landing. Inside the car is located a series of buttons, one button corresponding to each landing. When the passenger enters the car and closes the landing door and car gate he momentarily presses the button corresponding to the desired landing. The car then travels to that landing and automatically stops. The control for elevators of this kind is substantially the same as for an elevator using a car switch, with the addition that a selector switch is provided which is driven either by the machine or by the elevator car and makes the connections that automatically stop the car at the desired landing. One form of selector is shown in Fig. 11.

Dual Control. Dual, or combination, car switch and push button control fills a demand where the service justifies the employment of an operator for only part of the time that the elevator must be in service. This demand comes in larger apartment houses, industrial office buildings, clubs, etc. Its first cost is higher than that of any other type, but due to the two different

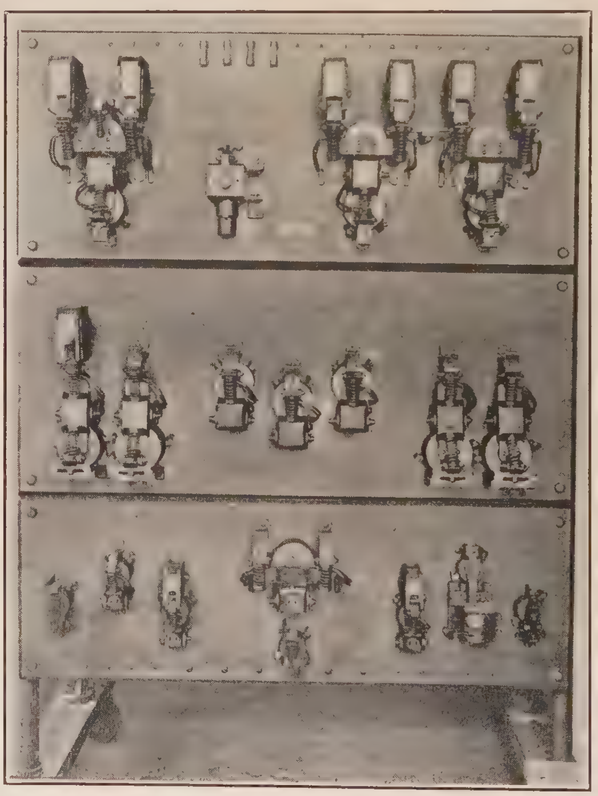


Fig. 9—D-C. Gearless Traction Elevator Controller

forms of control is somewhat more reliable than the straight push button control. Push buttons are provided at each landing for calling the car to that landing. A set of push buttons and a master switch is placed inside the car. Means are provided to render the push buttons within the car inoperative when the car switch is being used. At the same time the connections to

the landing push buttons are transferred to the annunciator operation.

Method of Acceleration

The elevator motor is automatically accelerated from rest to the operating speed. There are several methods for obtaining this automatic acceleration. Among the more common methods are the following:

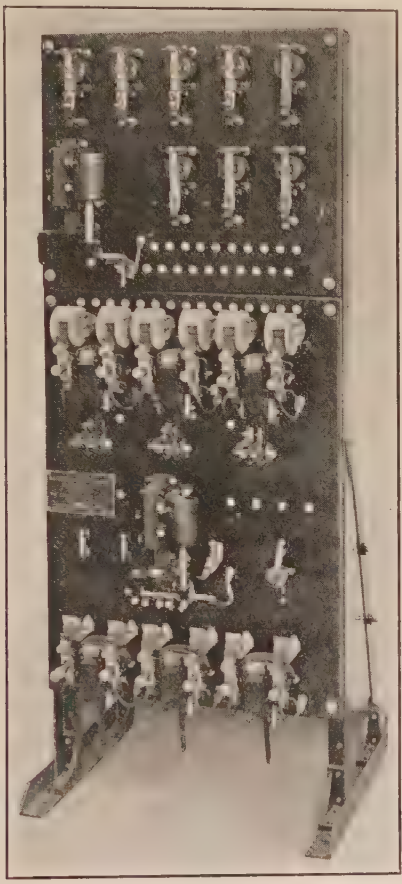


Fig. 10—A-C. Full-Magnet Elevator Controller
With floor selector relays for push-button operation.

Time Element Acceleration. This is based on the principle that time is required to accelerate the motor. Usually the device provides a definite time for acceleration independent of the load of the car. One of the most common devices of this type is a dash-pot, either air or oil.

The advantage of this method of acceleration is the smooth start which it provides under all conditions of loading. Sufficient resistance can be provided to start the car smoothly with a light load. With a heavy load the timing device short-circuits sections of resistance until the motor develops sufficient torque to accelerate the load. Well designed accelerators of this type are not materially affected by variations in line voltage.

Counter E. M. F. Acceleration. This method makes use of the principle that the voltage across the terminals of the elevator motor increases with the speed of the motor so that magnet contactors connected across these terminals have their magnetism increased with the speed of the motor and can be adjusted to short-circuit sections of the starting resistance corresponding to different motor speeds. These magnetic contactors when properly designed are not affected seriously by atmospheric conditions, dust, or dirt, and therefore should remain in adjustment. This method of acceleration is sensitive to a variation in line voltage, but elevators are usually connected to the same service lines that furnish the lighting for the building and the voltage regulation is generally very good. Where poor regulation exists, special devices can be used to compensate for voltage fluctuation. The starting resistor should permit the motor to develop sufficient torque to start the maximum load.

Current-Limit Acceleration. This method of acceleration is dependent upon the current taken by the motor during acceleration. The motor must draw sufficient inrush current from the line to develop the torque necessary to start hoisting the maximum load. After this load has been started from rest the friction decreases as the running friction is less than the static friction; therefore, a larger part of the motor torque is available to accelerate the load, and the motor increases in speed until the torque developed is just sufficient to balance the load. At this value of current a relay closes the contacts to the next accelerating switch which in turn accelerates the motor to a higher balance speed. This process is repeated until all of the starting resistance has been short-circuited. With this method of control the motor is accelerated at a constant torque value, and therefore it reaches full speed quicker with a light load than with a heavy load as more torque is available for acceleration.

All magnetic contactors require an appreciable time to close so that any control system using contactors will have some time element. By modifying the design of these contactors the time element can be

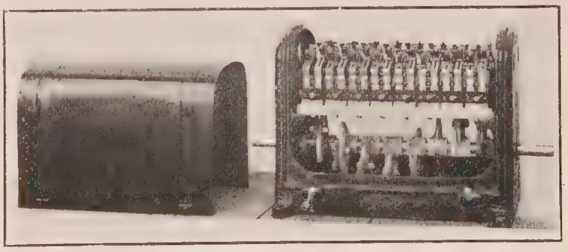


Fig. 11—Elevator Floor Selector

increased. This small time element is useful when the counter e. m. f. or current-limit method of acceleration is used to assist in giving a smooth start.

Another element which contributes towards smooth operation is the induction in the motor circuit. This inductive action checks the rush of current at the time a contactor short-circuits a section of armature resistance. The inductive effect may be increased by

adding an impedance coil to the circuit or by a special design of the elevator motor itself. The time constant of the motor may be increased by several well known methods, thus smoothing out the transition between the steps in the controller.

An elevator motor may be accelerated by a combination of two or more of these methods. As pointed out above, there is always some time element in every contactor, which may be increased by special design, this giving a combination of *time element* acceleration with either *counter e. m. f.* or *current-limit* acceleration.

V. Methods of Speed Control. The speed control of the elevator motor is very closely associated with the method of acceleration and may assist materially in smoothing out this acceleration. The method of speed control depends upon the type and design of motor. Some of the methods are as follows:

By Adjusting the Field Strength of the D-C. Motor. Most direct-current motors can be operated at different speeds by simply changing the strength of their fields. The range of speed obtained depends upon the design of the motor. If a considerable change in speed is required by this method, a larger and more expensive motor is required than for the ordinary constant-speed design. If the motor is massive and responds slowly to a change in field strength, very little difficulty is introduced by this method of speed control. If, however, the motor responds quickly, relays or other devices are used to limit the current during the change in speed. This method of speed control is very popular, particularly for the higher-speed, geared elevators. This is a very economical method of speed control.

By Connecting Resistors in Series and in Shunt with a D-C. Motor Armature. The shunt resistor has a stabilizing influence and limits the speed variation under different conditions of loading. This method of control is very commonly used to obtain the low speed from which a landing is made. With the same amount of resistance the speed will vary considerably, depending upon whether the motor has a positive or negative load, but for making a landing this speed range is not too great to obtain practical results. It is the least economical method of speed control of a d-c. motor and is therefore, generally used only for obtaining the landing speeds.

By Applying a Variable Voltage to D-C. Motor Terminals. The best known system of this kind is where a separate generator is used for each motor, the generator field being changed to obtain the different motor speeds. Where the generator is properly designed the elevator motor can be operated from rest to full speed in either direction by changing the strength and the direction of the generator field. A good arrangement for the motor-generator set is to use a single motor driving two generators in order that the elevators may be shut down in pairs to eliminate the standby losses.

By Applying Several Different Voltages to the Terminals of a D-C. Motor. These different voltages are usually obtained from a motor-generator set having several different generators, each generator providing a different voltage. The transition between voltages is obtained by inserting resistance in the armature circuit. With this method of control it is necessary to reverse the armature connection to reverse its direction of rotation. One motor generator set usually supplies several elevators.

Where a storage battery is available the intermediate values of voltage may be obtained by taps taken from this battery.

The last two methods of control have been used to a limited extent. These increase the first cost of the installation but may reduce the cost of power by eliminating most of the rheostatic loss during acceleration and slowdown. This is of particular advantage in cases where the elevator motor has little speed regulation by shunt field control.

By Changing the Number of Poles of an A-C. Motor. These motors are of the induction type and may have either squirrel-cage or wound secondaries. They are usually provided for two different pole combinations; one, a large number of poles giving a low speed from which the landing is made and the other a smaller number of poles providing the regular running speed. The primary may have either two sets of windings, one for each set of poles, or a single set of windings arranged for two sets of connections. The introduction of the two-speed a-c. motor has enabled the operating speeds of a-c. elevators to be materially increased. One of the most popular combinations is a 3 to 1 ratio, although motors are now built with a 6 to 1 ratio.

By Changing the Frequency of Power Supply to an A-C. Motor. This method of control has been very little used up to the present. The most convenient method of obtaining the reduced frequency is to provide a small frequency changer which can be connected to the primary of the elevator motor when a low speed is desired for making a landing.

Details

The elevator controller is made up of a number of unit parts, each of which performs a function in controlling the elevator. The parts usually found in a controller together with their functions are as follows:

1. A line switch for disconnecting one side of the motor from the line. This switch may be operated every time the car is moved or it may remain normally closed and be opened by a safety device or by failure of line voltage.

2. Reversing switches which change the direction of rotation of the motor and are normally used for opening and closing the motor circuit. Some of these switches operate each time the car is moved. For magnet control either two double-pole or four single-pole switches are used.

3. The accelerating device which automatically

short-circuits the starting resistance when the motor is being brought from rest to the operating speed. A similar device may be used to limit the armature current when the field strength is changing.

4. A dynamic brake for slowing down the d-c. motor when the elevator is brought to rest. This brake consists of an electric connection between the motor terminals and a set of resistors. The switches for making these connections may form part of the reversing switches or may be separate units, the number depending upon the car speed and the type of motor.

5. A mechanical brake for making the final stop and holding the car securely at the landing. This brake is usually applied by a spring and released by a magnet.

6. Terminal stops for bringing the car gradually to rest at either limit of travel independently of the operator. Usually two different devices are used for this purpose, one of which operates normally and the other an emergency device as previously explained. The second set is generally known as *overtravel limit switches.*

7. Some means in the elevator car which will enable the operator to control the elevator. This may consist of a rope or a lever, a car switch or a set of push buttons depending upon the method of control.

8. A safety switch in the car for stopping in case of failure of the regular operating means.

9. A slack cable device for stopping the motor in case the car or counterweight is obstructed in its travel. A device of this kind is required only for drum machines.

10. High-speed elevators usually have a switch operated by the speed governor which automatically reduces the motor speed if it exceeds a predetermined limit.

11. Gate or door switches to prevent operating the elevator until all doors or gates are closed.

12. Every controller should provide overload protection. This may consist of fuses, but is usually a circuit breaker, or an overload relay operating in conjunction with the main line contactors.

13. Where the operating device in the car is not self-centering, low-voltage protection should be provided, to prevent the accidental starting of the elevator after failure of power until the operating mechanism has been returned to the "off" position. For a-c. elevators this device usually protects against the failure of power in any phase of the supply circuit.

14. Alternating current motors should have protection against an accidental reversal of phase which would cause them to operate in the wrong direction.

15. The higher-speed elevator controllers provide for a low-speed for making a landing. Sometimes the control provides for several operating speeds less than the maximum running speed.

16. A floor leveling device is sometimes included as part of the control. This consists of automatic means for bringing the car platform level with the landing and maintaining it in this position.

Each type of elevator requires its own special form of control. The lower-speed machines require a less complicated control than when the elevator is operated at a higher speed. Often freight elevators have different requirements from passenger machines. Considerable skill and experience is required in the designing of control equipment and selecting the necessary features. Each control should contain all of the features necessary for a successful operation, but any additional features add to the complication and may be undesirable.

V—BRAKES AND OTHER SAFETY ACCESSORIES

Brakes and other safety accessories have little to do with power application to electric elevators but they are so vitally a part of the elevator equipment that a good idea of the complete elevator plant cannot be obtained without a complete understanding of these features.

Brakes

While the brake is a small part of an elevator machine it is an exceedingly important part. Because of the frequency of starts and stops it is highly essential that the car be brought to rest quickly and without shock or jar to the passengers. Also once brought to rest it is just as important that the car be maintained in its position in the hoistway while passengers are leaving and entering it. The functions of bringing the car to rest and maintaining it in a stationary position are obtained by the brakes. Elevator brakes are divided into three classes,—mechanical, dynamic and magnetic.

Mechanical Brakes. The straight mechanical brake is little used. To some extent it is still being installed on hand rope controlled freight elevators and sidewalk lifts. Most states prohibit its use on any passenger elevators because of its lack of protection to the car and occupants. As the name implies, it is simply lined brake shoes bearing against a pulley on the motor shaft. It is applied manually with the hand rope within the car, and automatically at the terminal landings by the traveling nut mechanism on the machine which has the double duty of returning the reversing switch to neutral, interrupting the motor circuit; and applying the mechanical brake. If, during operation, the voltage fails, the brake will not be automatically applied.

The mechanical brakes gives smooth results in stopping because a gradual application may easily be made by properly manipulating the control rope.

Dynamic Brakes. In the app ication of dynamic braking, advantage is taken of the ease with which a direct-current motor may be converted into a direct-current generator. The shunt field either partially or fully energized is connected to the line, and the

revolving armature is shunted with a resistor. Thus the motor operates as a generator and "pumps" current through the dynamic braking resistor thereby converting the mechanical energy of rotation into electrical heat. While this type of brake alone will not bring an elevator to rest, particularly if the load is overhauling, it will materially reduce the speed so that from that

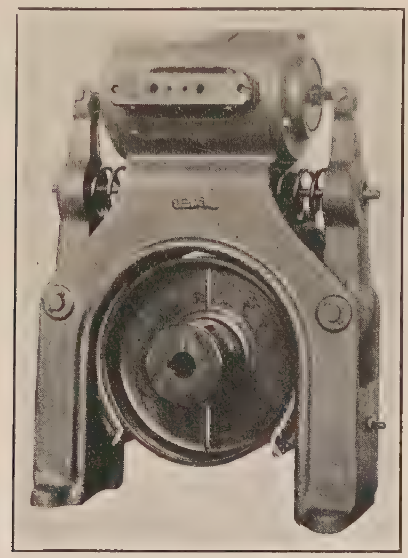


FIG. 12—D-C. MAGNET-OPERATED ELEVATOR BRAKE

speed the magnetically operated brake may easily be depended upon to bring the car to a safe and smooth stop. On the higher-speed d-c. elevators a graduated dynamic braking is furnished, which provides a braking more nearly proportional to load and speed conditions.

With alternating current, a braking effect similar to direct-current dynamic braking is sometimes furnished when a two-speed motor is used. In this case the low-speed winding is connected to the supply lines while the armature is rotating above the synchronous speed of this winding. Thus the motor acts as a self-excited induction generator and a powerful "dynamic" braking is obtained to bring the motor down to the synchronous speed of the low-speed winding. In this case energy is restored to the line during the braking period.

Direct-current dynamic braking is wasteful of electrical energy because the energy of rotation is lost in heat. The same applies to the mechanical brake where the energy is absorbed in the brake shoes. No effective method, economical of electrical energy, has been devised for quickly slowing down and stopping an elevator, although a direct-current motor with a wide speed range by shunt field control is economical in slowing down, as is also the two-speed alternating-current motor referred to in the preceding paragraph. (See Part III.)

Magnet Brakes. The importance of the magnet brake particularly on alternating current cannot be over emphasized. See Figs. 12 and 13. The reasons for its great importance have been outlined in Part III under the subject of "The Elevator Motor."

The magnet brake consists of brake shoes, similar to those used with the mechanical brake, operated by an electromagnet. This type of brake should always be used in addition to any other, except for low-speed freight sevice, for the purpose of positively holding the car stationary at the will of the operator.

On direct current, the magnet brake has been a small problem, but on alternating current it becomes a difficult one because of difficulties in satisfactory magnet design. Various types of magnets are being used, such as single-phase long-stroke, polyphase long-stroke, polyphase short-stroke and constant-stroke. The constant-stroke magnet is no more than a small motor designed to remain across the line with the rotor stalled. This magnet is sometimes called a *torque motor.* This type of magnet does not seal. It is difficult to keep quiet an alternating-current magnet that does seal. It is liable to slam in closure, and unless the laminated parts are perfectly surfaced and perfectly aligned it will hum after closure. A dash-pot is sometimes used for long-stroke magnets to reduce the slap in closing, and sometimes the entire magnet is immersed in oil to deaden the noise. One type of constant-air gap magnet, which is very quiet, absorbs the energy of rotation in a small auxiliary mechanical brake.

It is realized that if a mechanical brake action could be accomplished automatically in a magnet brake, smoother stopping results on alternating current could be obtained. Three manufacturers have tried the fol-

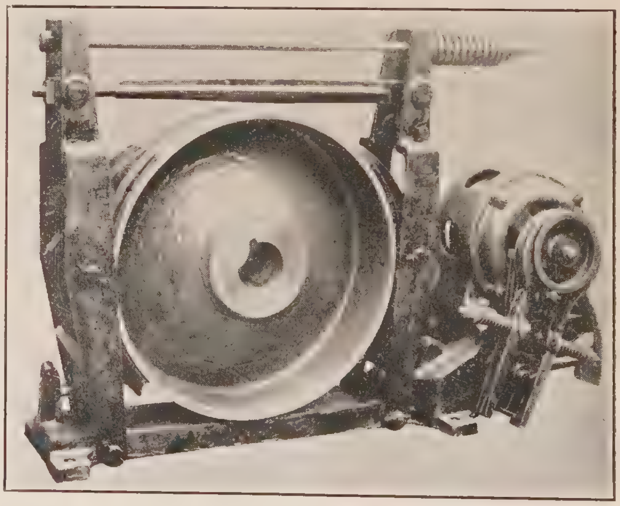


FIG. 13—A-C. ELEVATOR BRAKE WITH CONSTANT AIR-GAP MAGNET

lowing schemes: A single magnet with the main brake spring partially counteracted by a weaker spring is used, and a dashpot is so arranged that the brake shoes are applied with partial pressure which quickly increases to maximum. The main objections to this are the use of a dashpot and the fact that the operator

does not have any control over the weak and strong settings. Another scheme is the use of two independent magnets or complete brakes, in which case the operator has control over the weak and strong settings, giving good stopping results. The objection to this is the use of two magnets. The third method consists in the use of a single short-stroke polyphase magnet with a variable reactance in the magnet circuit proportioned

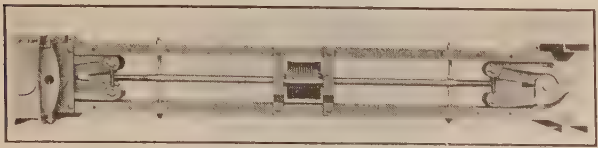


FIG. 14—ELEVATOR SAFETY GUIDE GRIPS

to break the seal of the magnet but still maintain sufficient current in the brake coils to partially counteract the brake spring tension. As the car control switch is moved towards the "off" position, this reactance is decreased so the action of a mechanical brake is practically reproduced. This has worked out sufficiently well so that it is being used on elevators driven by single-speed motors and running 300 ft. per min. An objection to this method is the noise which is always present to some extent when the reactance is cut into circuit.

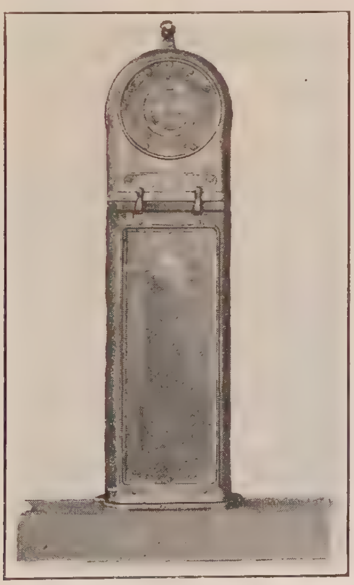


FIG. 15—ELEVATOR CAR OPERATING SWITCH

The last two types must be so wired that there will be no way for the operator to hold the weak brake condition when the car is close to the terminal landings.

As a safety measure all magnetically operated brakes are so designed that the brake is released by the magnet and applied by springs or weights, so that a failure of power will always stop the elevator.

SAFETY DEVICES

These may be classified as electrical and mechanical. The mechanical are so closely allied to the electrical that they will be briefly described. The principal safety devices are, guide grips and overspeed governor with governor switch, car-operating switch, car safety switch, terminal-limit switches, overtravel-limit switches slack-cable switch, door switches, compensating-cable-sheave switch, buffers and air cushions.

FIG. 16—CAR SAFETY SWITCH

Guide Grips and Overspeed Governor. Guide grips have been made in a number of different types such as eccentric, dog, roller, and wedge, the wedge type now being almost universally adopted. See Fig. 14. The mechanism, is mounted below the car with a small winding drum which is connected to the overspeed governor by a steel cable. The holding of this cable at excessive car speeds rotates the drum so that the wedges force the grips against the guide rails and stop the car.

Usually a fly-ball type of governor is used in connection with the guide grips so arranged that the cable referred to rotates the governor shaft. The governor is arranged with a grip so that if the normal speed of

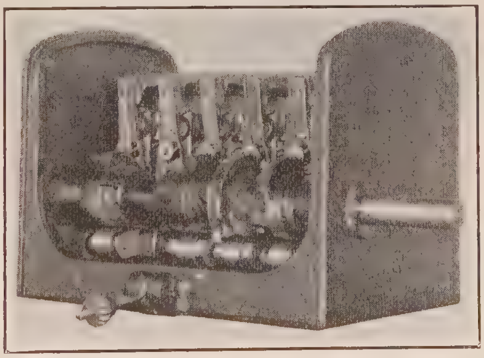


FIG. 17—MACHINE LIMIT SWITCH FOR DRUM-TYPE ELEVATOR

the elevator is exceeded by a fixed amount it holds the governor cable and effects the setting of the guide grips.

It is accepted practise to install a control switch on the governor, so adjusted that the switch will trip to open the control circuit and disconnect power from the motor at a speed lower than the speed at which the guide grips act. This switch prevents the guide grips from setting in case of a slight overspeeding. The switch is arranged so that it cannot be reset unless the guide grips are in the running position.

Car-Operating Switch. The car-operating switch usually has the automatic return or self centering feature so that if the operator's hand is removed from the lever it will return to the off position. See Fig. 15. It also is ordinarily provided with a center latch so arranged that any accidental leaning against the switch will not move the lever to the running position.

Car Safety Switch. The car safety switch is for the purpose of stopping the car in emergency in case of the failure of the car operating switch. Fig. 16. It is wired in a separate cable of opposite polarity to the car-switch cable, so that in case of grounds, etc., in the car-switch cable, the car safety switch will not be thrown out of commission.

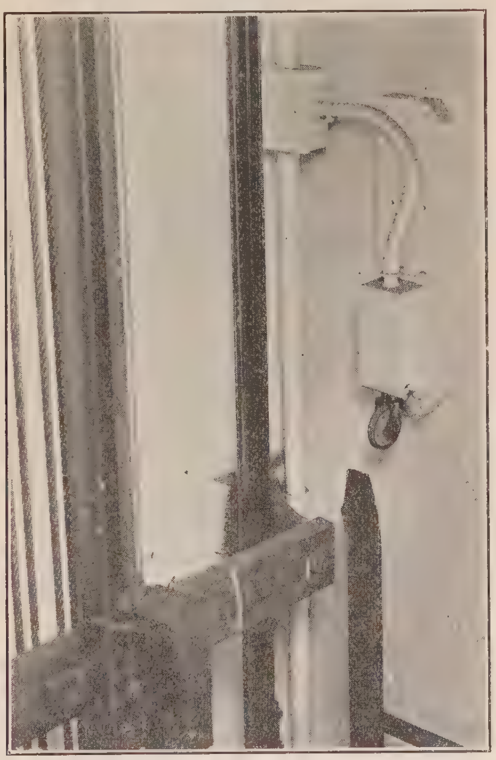


Fig. 18—Installation of Elevator Hoistway Limit Switch

Terminal Limit Switches. These act each time the car approaches the terminal landings, and function to bring the car to rest at these landings in case the operator is careless. See Figs. 17 and 18. They may be mounted on the car and operated by cams in the hoistway or vice versa for a traction-type elevator. These may also be used on a drum-type elevator although frequently limit switches geared to the elevator machine are used instead.

Overtravel-Limit Switches. Overtravel hoistway limit switches, Fig. 18, are always mounted in the hoistway and are operated by cams on the elevator car. They are placed beyond the normal range of car travel, and function to stop the car in case of the failure of the regular terminal stop limits. It is very desirable and the usual practise to arrange the connections to these limits so that the car cannot be backed out of them by manipulating the car switch. This gives an added safety feature as it requires the operator to call the attention of an electrician or someone connected with the maintenance department to the fact that the car ran into the overtravel limits, and have the cause of this overrunning corrected.

Fig. 19—Slack-Cable Switch

Slack-Cable Switch. Ordinarily this is used on a drum-type elevator to open the control circuit in case of slack cable caused by the car or counter-weight being caught in the guides. It is operated automatically when the cables slacken. See Fig. 19. It is sometimes mounted on top of an elevator car of high travel traction elevators where the cable weight is so great that the machine may not entirely lose traction in case of the bottoming of the car.

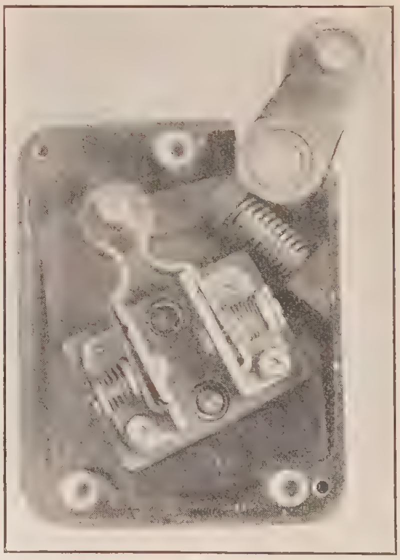


Fig. 20—Elevator Door Safety Switch

Door Safety Switches. These, Fig. 20, in combination with door locks, prevent the car from operating

unless all doors are closed and locked. The design requirements of these devices are in many cases regulated by safety codes. There are numerous types manufactured and many have little value, so that door locks and switches should be investigated before installing. Some combinations lock the car-operating switch in neutral while the door is open. Others interrupt the car-control circuit when the door is open. Because the large majority of elevator accidents are due to not using suitable door interlocks, it is advisable to use them even though it decreases the service of the elevator to some extent. (See Part I.)

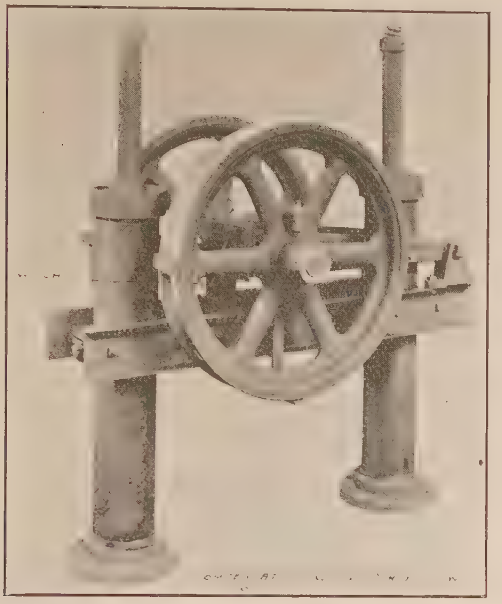


Fig. 21—Elevator Compensating Cable Sheaves with Switch

Compensating Cable Switch. This is connected so that it is opened by the lowering or raising of the compensating cable sheaves in the pit. See Fig. 21. The switch interrupts the control circuit and stops the car should the sheaves lower to any appreciable extent due to cable stretch. Also, in case of the car or its counterweight being caught in the guides, the compensating cable sheave will raise and operate the switch to cut off power.

Buffers and Air Cushions. A buffer is always required under the car. For lower speeds a spring alone is used, but for higher speeds a combination of oil dash-pot and spring is used, Fig. 22. These must provide a retarding effect so that maximum retardation will not exceed 64.4 feet per second per second.

At one time an air cushion was required for certain service in certain localities. This consists of a hoistway practically air tight at the lower end for a certain percentage of the total height. This involved very expensive enclosure construction and while effective in retarding the motion of a falling car it is understood the air cushion has been practically abandoned as unnecessary to safety. Another disadvantage of this scheme is the additional power required to move the car due to air friction.

Protective Devices

Besides the various forms of brakes and safety devices above described most elevators are protected against abuse by the following apparatus:

Main Line Service Switch and Fuses. These are mounted in an accessible location in the elevator machine room and are usually enclosed in a metal cabinet, preferably with an externally operated knife switch, and with a mechanical interlock making it necessary to open the knife switch before the cover can be opened to inspect or replace fuses.

Circuit Breakers and Overload Relays. Circuit-breaker protection of individual elevator motors is not very often used inasmuch as the National Electrical Code requires fuse protection of elevator motors even when circuit breakers are used.

Frequently, however, in addition to the service fuses, overload relays are used in order to secure protection against overloading of the elevator itself. The overload relays are set below the fuse rating so as to prevent the blowing of fuses. The overload relays are sometimes made to reset automatically with the return of the operating switch handle to neutral, so that after an overload it is unnecessary to go to the elevator machine room to again place the elevator in operating condition.

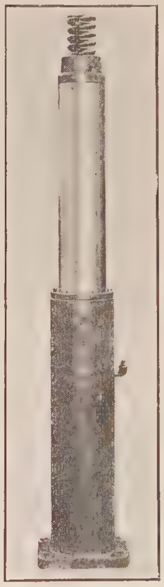


Fig. 22—Elevator Oil Buffer

Overspeed Slow-down Relay. Some builders include in their electrical equipment a voltage relay so connected that an overspeeding of the elevator in either direction will cause the relay to act and thus automatically retard the speed. This relay is set to act at a speed below that at which the overspeed governor is set.

Phase-Failure Protective Relay. All alternating-

current elevator installations on which the elevator motor may be continuously connected to the lines, such as hand-rope and push-button controlled elevators, include some form of phase-failure protection. Otherwise, upon the failure of a phase, the motor may be stalled on the single-phase condition, and burn out. The protective relay is usually a polyphase, shunt-wound relay with a control-circuit contact to maintain the control circuit of the elevator controller so long as the phases are all alive. The failure of any phase causes the relay to open the controller circuit and thus disconnect the motor from the supply lines.

Phase-Reversal Protective Relay. Many State electrical codes now require a phase-reversal protective relay on all polyphase a-c. installations. Frequently the phase-failure and phase-reversal relays are combined in one device. The reversal of phases immediately opens the controller circuit and prevents the elevator motor being connected to the lines until the relation of the phases is corrected.

VI—POWER CONSUMPTION

Anyone connected with building or industrial plant operation is interested in the power consumed by electric elevators. The architect and engineer are interested. The building owner is interested. From a conservation standpoint, everyone interested in the country's welfare is anxious to see the most economical use of electric power for all purposes.

Determining Factors

There are so many factors entering into this problem that it is impossible to give any accurate power consumption figures for any one type of elevator with a given capacity and running at a given speed, with a specified load on the car and with a specified number of stops per mile of car travel.

The operator himself is one of the variables. Some elevator operators run their cars to good advantage from a power economy standpoint, but many others are most careless in the way they operate.

Besides the operator's effect on economy other variables are inertia (including the weights of the car, counterweights, lifting ropes, balancing ropes, or chains, all moving parts of the machine etc.), rate of acceleration, and design and construction of all parts entering into the complete elevator. To show the importance of these factors, one company may design an elevator for a capacity of five tons that will have in its make-up approximately one half the material that another company may deem advisable for the same capacity and speed. When it comes to power consumption the lighter weight apparatus will naturally win out, even though it may not last long, due to its light construction. Therefore tests showing power consumption are naturally subject to all the variations that are inherent in elevator manufacture which is still somewhat lacking in standardization.

Regardless of all these variables it is of course possible to quote actual test figures for various types of elevators so that a general idea of the power consumed may be obtained.

The power consumption of electric elevators ranges from two to three kw-hr. per car-mile up to ten or more depending upon the variables mentioned above, but depending mostly upon loads, speeds, rate of acceleration, and number of stops per car-mile. Elevators make as many as 25 miles of travel per day so that even in a day's time the total energy consumption in a large office building is considerable and should be kept down to a minimum.

Results of Tests

Geared, Drum-Type Elevators. An average of several drum-type, geared elevators, with capacities between 2000 and 2500 pounds, at 350 to 400 ft. per min. regular service indicates the following results:

Capacity	Speed	Total miles per day	Kw-hr. per car-mile
2000	350	11.25	3.98
2500	400	10.90	4.35
2000	400	15.20	3.58
Average		12.45	3.97

Gearless Full Wrap Traction, 1 to 1 Roping. The following results were obtained from actual test of an elevator rated at 2500 lb., 500 ft. per min. with 800 lb. over-counterweight. Values are averaged for up and

Stops per car-mile	Kw. hours per car-mile	
	Balanced	Full load
0	1.20	1.82
50	2.22	3.39
75	2.90	4.07
100	3.50	4.80
125	4.10	5.46
150	4.28	5.93
200	5.12	7.10
250	5.81	9.07
300	6.50	9.20
400	7.90	11.50

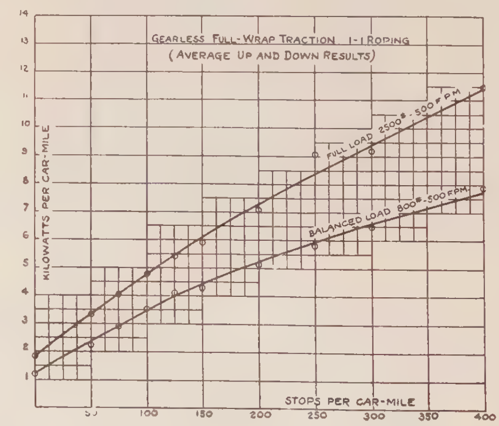


Fig. 23—Results of Test of Gearless Full-Wrap Traction Elevator, 1-1 Roping

Values averaged for up and down operation.

down operation. The results are plotted in Fig. 23. The curves clearly show the variation in power consumption with load changes and with variation in the number of stops per car mile.

Another set of tests on a gearless 1 to 1 machine rated at 2500 lb., 500 ft. per min., in a ten-story office building gave the following results. These are up and down averages. The car weighed 3900 lb. and there was 1060 lb. over-counterweight.

52 Stops per car-mile							
Load in lb.	Operator	666	1060	1360	2010	2360	2660
Kw-hr. per car-mile	2.35	2.08	1.95	1.87	2.15	2.50	3.22
104 Stops per car-mile							
Load in lb.	Operator	666	1060	..	2010	..	2660
Kw-hr. per car-mile	3.09	2.86	2.52	..	2.92	..	3.86
208 Stops per car-mile							
Load in lb.	Operator	666	1060	..	2010	..	..
Kw-hr. per car-mile	4.91	4.19	3.98	..	4.25	..	..
416 Stops per car-mile							
Load in lb.	Operator	666	1060	..	2010	..	..
Kw-hr. per car-mile	7.29	6.75	6.7	..	7.43	..	..

A test was made in a fifteen story building. The elevator was rated at 2750 lb. at 500 ft. per min. The regular service test with approximately 100 stops per car mile gave an energy consumption of between 3.32 and 4.73 kw-hr. per car-mile.

The effect of increased number of stops is shown in the following results obtained from a test in a 22-story office building:

Empty	—Stopping at every floor	6.4 kw-hr. per car-mile
Full Load	—Stopping at every floor	10.4 " " " " "
2/3 Load	—Stopping at top and bottom only	2.4 " " " " "
2/3 Load	—Stopping at every floor	8.8 " " " " "

A 22-floor 600 ft. per min. elevator with express service to the tenth floor and local service from the tenth to the twenty-second floor, traveling an average of 22 miles a day consumed 3.5 kw-hr. per car-mile. Local elevators in the same building operating at 400 ft. per min. traveled nine miles per day and consumed an average of 4 kw-hr. per car-mile each.

Gearless Full-Wrap Traction Elevator 2 to 1 Roping. The only tests available for publication are shown in the following table. The elevator was rated at 3000 lb., 500 ft. per min., 1175 lb. over-counter-weight was used. Average up and down results are given:

Stops per car-mile	Kw-hr. per car-mile	
	Balanced	Full Load
0	2.00	3.80
50	2.90	4.60
75	3.40	5.40
100	3.90	6.00
125	4.33	6.95
150	4.81	7.80
200	5.80	8.71
250	6.78	10.40
300	7.68	11.10
400	9.06	15.20

Geared Half-Wrap Traction Elevator. A test was made on several elevators rated at 2500 lb., 600 ft. per min., with the following average up and down results:

Stops per car-mile	Load in lb.	Kw-hr. per car-mile
16	1100	2.06
80	"	4.20
96	"	4.70
16	2500	2.40
80	"	4.80
96	"	5.20

An elevator running 400 ft. per min. serving an 18-story building and traveling an average of 21.8 miles per day showed a regular service consumption of 3.28 kw-hr. per car-mile.

Another at the same speed in a 13-story building and traveling 19 miles a day consumed 3.88 kw-hr. per car-mile.

The average of a lot of 400 ft. per min. elevators was 3.8 kw-hr. per car-mile.

The following test results were obtained with an elevator having a capacity of 2250 lb. at 500 ft. per min. The over-counterweight was 580 lb. In this case the motor had a 3 to 1 speed variation by shunt field control. Had there been less or no control by shunt field variation the power consumption values would have been considerably higher. (See Part III.)

Stops per car-mile	Kw-hr. per car-mile	
	Balanced	Full Load
0	1.50	2.05
50	2.10	3.00
75	2.50	3.43
100	2.92	3.90
125	3.30	4.46
150	3.57	4.90
200	4.23	5.91
250	5.30	6.70
300	5.90	7.55
400	6.95	8.50

Lack of proper maintenance will also increase the power consumed. It is evident that all moving parts such as the machine itself, sheaves, guides, etc. must be properly lubricated at regular intervals in order to insure the most economical results. Also if the brakes are not properly adjusted the operators will find difficulty in making accurate stops without inching and the resultant loss in power.

Conclusion

While the above test figures are of interest they actually are of little comparative value on account of the many variables indicated under "Determining Factors." Some years ago the Cincinnati Gas & Electric Company made some operating cost tests on a great many elevators in its district. The averages of all these tests are given as follows:

Freight	Cost per elevator	$8.00 per month	
"	" " h. p.	1.09 per month	
Passenger	" " elevator	14.64 per month	
"	" " h. p.	1.26 per month	

These are, of course, costs for power only, and would not apply with present-day power costs.

Attention is called to the fact that the big determining factor in the cost of elevator operation lies in the number of starts and stops and not in the load carried by the car.

Ways in which Operation and Maintenance Affect Power Consumption

It has already been mentioned that the operator himself is one of the important factors determining the power consumption of electric elevators. It is interesting to note how this factor affects the results.

If an operator is so expert that he slows down the car as nearly as possible to the landing at which he is to stop and if he stops the car accurately with the landing without "inching" he reduces the current used in slowing down or running at low speed and reduces the number of starts and stops by eliminating the inching operation so frequently used by unskilled operators. Besides this he improves the service of the elevator which point is of vital consideration.

Evidently from the manner in which many elevators are run little attention is paid to this important factor in elevator economy. If building owners would realize the importance of this point it would be possible by careful instruction and competition between operators to materially cut down the power consumption on many installations.

Towards this end a watt-hour meter might be installed on each elevator. Also car-mile recorders and counters for registering the number of stops could be added. In this way accurate data on the performance of each elevator could be obtained. If an operator is assigned to a particular machine a bonus might be paid to the operator who showed unusual saving in power consumption due to skilful operation. In a large building this would set up a rivalry between operators and might be very beneficial from the standpoint of the power consumed.

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CAPACITY EFFECTS IN INDUCTANCE COILS

A coil of wire wound in any of the familiar forms called "inductance coils" behaves in an electric circuit primarily as an inductance. The potentials of the different parts of the coil are, however, different from each other and from the potential of the ground. For this reason, the coil also behaves to a certain extent as an electric condenser, or rather a system of condensers.

On account of the importance in radio communication of capacity effects in inductance coils, careful studies of these effects, both theoretical and experimental, have been made at the Bureau of Standards, Washington, D. C. An interesting result which has been found is that one effect seems to depend primarily on the capacity of the coil to ground. This effect is observed when two condensers in series are connected across the terminals of the inductance coil, and the common terminal of the two condensers is grounded. If the inductance coil possesses capacity to ground, the familiar criterion for resonance in the system, computed from the known value of the capacities of the two condensers, will not apply.

If both condensers are variable, and the system is adjusted for resonance by successively assigning arbitrary values for the setting of one condenser, and then tuning with the other condenser, it would be expected from elementary considerations, neglecting the effects of distributed capacity, that the successive resonance values of the capacity of the two condensers in series, determined as the product of their capacities divided by their sum would be constant. On account of the distributed capacities, this simple relation does not hold. It is found, however, that under the conditions above mentioned, with the common terminal grounded, the capacity of the two condensers in series determined as the product of their capacities divided by their sum, is linearly related to the reciprocal of the sum of their capacities. This relation has been verified both mathematically and experimentally.

The results of both the mathematical and experimental investigation of this particular phase of the problem of capacity effects in inductance coils are given in a publication of the Bureau of Standards, Scientific paper No. 427, "Some Effects of the Distributed Capacity Between Inductance Coils and the Ground."

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

A. I. E. E. Midwinter Convention

FEBRUARY 15-17, 1922

The tenth annual Midwinter Convention of the American Institute of Electrical Engineers will be held February 15-17, 1922, in the Engineering Societies Building, 33 West 39th Street, New York, N. Y. This will be the first convention to be held under the new ruling of the Board of Directors which prescribes but four general technical meetings of the Institute to be held each year. Owing to this reduced number of general meetings an unusually large attendance is anticipated and every effort is being made to make this meeting of particular interest.

The registration bureau will be in the main entrance hall of the Engineering Societies Building and will open at 11:00 o'clock Wednesday morning, February 15th. Members and guests are requested to register promptly on their arrival at the building, as such action greatly facilitates the work of the various committees.

Beginning with Wednesday afternoon, five technical sessions will be held for the presentation of papers. The Thursday evening session will be devoted to the presentation of the Edison Medal to Cummings C. Chesney, followed by a lecture by Dr. W. D. Bancroft. Friday afternoon has been left open for members to make inspection trips to places of engineering interest, and on Friday evening the annual dinner-dance will be held.

PROGRAM

Wednesday Morning, February 15—11:00 A. M.

Registration of members and guests.

Wednesday Afternoon—2:30 P. M.

Technical Session

1. *The Key West-Havana Submarine Telephone Cable System*, by W. A. Martin, G. A. Anderegg and B. W. Kendall.
2. *Submarine Cable Telegraphy*, by J. W. Milnor.
3. *Printing Telegraph Systems Applied to Message Traffic Handling*, by A. H. Reiber.

Wednesday Evening—8:30 P. M.

Technical Session

4. *Questionnaire on Lightning Arrester Practise*, by F. L. Hunt. (From the 1921 Annual Report of the Protective Devices Committee)
5. *On Deviations from Standard Practise in Lightning Arresters*, by E. E. F. Creighton.
6. *Condenser Discharge Through General Gas Circuits*, by Charles P. Steinmetz.

Thursday Morning, February 16—10:30 A. M.

Technical Session

7. *The Petersen Earth Coil*, by R. N. Conwell and R. D. Evans.
8. *The Effects of Moisture on the Thermal Conductivity of Soils*, by G. B. Shanklin.
9. *Five Hundred Tests on the Dielectric Strength of Oil*, by J. L. R. Hayden and W. N. Eddy.
10. *An Analytical Investigation of the Causes of Flashing of Synchronous Converters*, by E. B. Shand.

Thursday Afternoon—2:30 P. M.

Technical Session

11. *The Use of Superimposed Imaginary E. M. Fs., Currents and Fluxes in the Solution of Alternating-Current Problems*, by V. Karapetoff.
12. *Questions on the Economic Value of the Overhead Grounded Wire*, by E. E. F. Creighton.
13. *Wave Form and Amplification of Corona Discharge*, by J. B. Whitehead and N. Inouye.
14. *Prevention of Transient Voltage in Windings*, by J. Murray Weed.

Thursday Evening—8:30 P. M.

Presentation of the Edison Medal to Cummings C. Chesney.
Lecture on Colloids, by W. D. Bancroft.

Friday Morning, February 17—10:30 A. M.

Technical Session

15. *Heating of Railway Motors in Service and on Test Floor Runs*, by G. E. Luke.
16. *The "Indumor,"* by V. Karapetoff.

The following papers are to be presented by title only:

17. *Skin Effect and Proximity Effect in Tubular Conductors*, by Herbert B. Dwight.
18. *Heat Losses in Stranded Armature Conductors*, by Waldo V. Lyon.
19. *Current Locus of Single-Phase Induction Motors*, by J. K. Kostko.
20. *Polyphase Commutator Machines*, by A. B. Field.

Friday Afternoon

Inspection Trips to Points of Engineering Interest (See announcement below.)

Friday Evening—7:00 P. M.

Dinner-Dance (See announcement below.)

INSPECTION TRIPS

The following companies have courteously offered to open their plants for inspection by members and guests, either individually or in groups, at the times indicated. The A. I. E. E. convention badge will be accepted as sufficient identification for direct admission to plants or for the issuance of passes where such are required. Complete information including directions for reaching plants can be obtained at registration booth.

Friday, February 17—2:00 P. M.

Fox Film Corporation—Studios and laboratory, 55th Street and 10th Avenue.

THE NEW YORK TELEPHONE COMPANY—Walker-Lispenard Building, including "Canal" exchange, Metropolitan Machine Switching Toll Board, Operating and Test Rooms of Long Lines Department, 24 Walker Street.

UNITED ELECTRIC LIGHT & POWER CO.—New Hell Gate Station.

BELL SYSTEM RESEARCH LABORATORIES—463 West Street.

RADIO CORPORATION OF AMERICA—Port Jefferson, Long Island.

Wednesday, Thursday and Friday, February 15, 16, 17. 10:00 A. M. to 4:00 P. M.

INTERBOROUGH RAPID TRANSIT CO.—59th Street and 74th Street Stations and Substation No. 42.

PUBLIC SERVICE ELECTRIC CO. OF N. J.—Essex Power Station, Newark.

UNITED ELECTRIC LIGHT & POWER CO.—Sherman Creek Power Station, 201st Street and Harlem River.

BROOKLYN EDISON CO.—Gold Street Station, Brooklyn.

DINNER-DANCE

A dinner-dance will be held at the Hotel Astor, Broadway and 44th Street, New York, Friday evening, February 17, 1922, at 7:00 o'clock. The purpose of the dinner-dance is to provide a social function for the entertainment of the members and their guests in attendance at the convention.

An informal reception will precede the dinner and prompt attendance is desired in order that the Entertainment Committee's arrangements may be carried out as planned.

The subscription price is $5.00 per person.

The tables will accommodate eight or ten persons each. Members are requested to make up parties of eight or ten or to state their seating preference to the committee. Communications should be addressed to the Committee on Entertainment, A. I. E. E., 33 West 39th Street, New York, N. Y.

A. I. E. E. Meeting in Chicago

APRIL 19-21, 1922

The second general meeting of the Institute for 1922 will be held in Chicago, April 19-21. The Meetings and Papers Committee and the officers of the Chicago Section have cooperated in the preparation of a program of technical papers and other items of interest which will assure a pleasant and profitable occasion to all who are able to attend this meeting. The papers to be presented are under the auspices of several of the technical committees, insuring a wide range in the variety of subjects. The program will be printed in full in the March JOURNAL.

Future Section Meetings

Atlanta.—February 23, 1922. Subject: "Bloom Mill Electrification." Speaker: Mr. S. N. Roberts, of the Atlantic Steel Company.

Baltimore.—February 17, 1922, Engineers Club, 8.15 p. m. Subject: "The Design and Construction of the Hell Gate Station of the United Electric Light and Power Company." Speaker: Mr. H. W. Leitch, of the United Electric Light and Power Company, New York City.

Cleveland.—February 21, 1922, Club Rooms of the Electrical League, Hotel Statler, 8:15 p. m. Subject: "The Superpower System." Speaker: Mr. W. S. Murray, of New York.

Erie.—February 21, 1922. Subject: "Safety Engineering." Speaker: Mr. M. C. Goodspeed.

Fort Wayne.—February 16, 1922. Subject: "The History and Future of Niagara." Speaker: Mr. Frank B. Taylor. Mr. Taylor is a geologist of national reputation and has a very interesting paper which will be illustrated by lantern slides.

New York.—A joint meeting of the New York Section of the Institute and the Metropolitan Section of the A. S. M. E. will be held on the evening of Friday, February 24, 1922 at the Engineering Societies Building, 33 West 39th Street, New York on the subject of "Central Power Station Operation." Complete details will be furnished the Section membership in a notice to be issued later.

Providence.—February 3, 1922, Providence Engineering Society's Rooms, 8.00 p. m. Subject: "Radio Telephony." Speaker: Mr. W. R. G. Baker, of the Radio Engineering Department of the General Electric Company.

Schenectady.—February 3, 1922. Subject: "An Evening With the Stars, Or, The Frontiers of the Universe." Speaker: Mr. B. R. Baumgardt, Lecturer, Scientist and Explorer.

February 17, 1922. Subject: "Magnetism." Speaker: Mr. L. T. Robinson, General Standardizing Laboratory, General Electric Company, Schenectady, N. Y.

March 3, 1922. Joint meeting with the American Society of Mechanical Engineers, American Chemical Society and Society of Engineers of Eastern New York. Speakers: Thornton Lewis, Vice-President and General Manager of York Heating & Ventilating Corporation, Philadelphia; and F. Paul Anderson, Director of Experiment Station of the American Society of Heating and Ventilating Engineers, Pittsburgh. The speakers will talk on general subjects of heating and ventilation.

March 17, 1922. Subject: "Recent Developments in High-Tension Practise and High-Voltage Phenomena." Speaker: Mr. F. W. Peek, of the General Electric Company, Pittsfield.

Toronto.—February 10, 1922. Electrical Building, Toronto University. Subject: "Construction Work." Speaker: Mr. F. M. Farmer.

Utah.—February 24, 1922. Subject: "Wireless on Wire Lines." Speaker: Mr. C. C. Pratt, Utah Plant Supt., Mountain States Telephone and Telegraph Company. In addition to the paper, Messrs. Pratt and Jeanne will conduct a tour of inspection through the telephone company's plant and illustrate the subject of Mr. Pratt's paper.

Vancouver.—March 3, 1922, Auditorium Board of Trade Building, Pender and Homer Streets, Vancouver. Subject: "Storage Battery Locomotives for Mine and Industrial Haulage." Speaker: Mr. T. H. Crosby.

Power Conference to be Held

NEW YORK, N. Y., FEBRUARY 7-8, 1922

The Water Power League of America will hold a power conference at the Engineering Societies Building, 29 West 39th Street, New York City, February 7th and 8th. The subject of amendments to the Federal Power Act, the canalization and power development of the St. Lawrence and the general subject of the power resources of the U. S. will be discussed at the conference.

All members of the A. I. E. E. are cordially invited to attend the conference and take part in the discussion. Admission will be by card which will be furnished upon application to the office of the Water Power League of America, 116 Nassau Street, New York City.

Polytechnic Institute, Brooklyn, N. Y.

LECTURES ON BUSINESS AND INDUSTRIAL PROBLEMS

The Polytechnic Institute of Brooklyn is conducting a course of lectures on local and national problems in their relation to the industries of the Greater New York District. The next meeting will be held on February 6th, 8:30 p. m., in the Polytechnic Institute Auditorium, Brooklyn, and the subject will be the transit situation in New York City. Mr. George W. McAneny, chairman of the Transit Commission, will be the principal speaker. Other meetings will be held from time to time, admission to which is by ticket. Tickets may be secured from the Office of the Registrar of the Polytechnic Institute, 99 Livingston Street, Brooklyn, N. Y.

American Engineering Council

ANNUAL MEETING, WASHINGTON, JANUARY 5-6, 1922

The first Annual Meeting of the Federated American Engineering Societies was held at the Cosmos Club, Washington, January 5th and 6th.

President Mortimer E. Cooley, in opening the first session, declared his confidence in the future of the Federation, and outlined plans for more effective organization. He also announced that he would soon start on a tour of the South and Southwest, during which he would address many meetings of engineers for the purpose of informing them regarding the functions and scope of the Federation in utilizing the services of the engineering profession in the advancement of public welfare.

Officers were chosen; the work of the past year reviewed and discussed; action taken on important matters of public and technical service; new financial arrangements put into effect; committees named; new policies sanctioned and old ones reshaped; and a broad program outlined for the next twelve months.

Election of Officers

The balloting for officers resulted in the reelection as Vice-Presidents of Dexter S. Kimball, Dean, College of Engineering, Cornell University; and J. Parke Channing, of New York; W. W. Varney of Baltimore was again chosen Treasurer.

Mortimer E. Cooley had previously been elected President, and Messrs. Calvert Townley, of New York, and W. E. Rolfe, of St. Louis, are hold-over Vice-Presidents.

The above named six officers together with the following constitute the Executive Board of the American Engineering Council which is the governing body of the Federation, for the year 1922: H. E. Howe, Washington, American Institute of Chemical Engineers; Prof. C. F. Scott of Yale, L. B. Stillwell of New York, J. H. Finney of Washington, William McClellan of Philadelphia, and L. F. Morehouse, of New York, representing the American Institute of Electrical Engineers; A. S. Dwight of New York, Charles H. MacDowell of Chicago and Philip N. Moore of St. Louis, the American Institute of Mining and Metallurgical Engineers; L. P. Alford of New York, E. S. Carman of Cleveland, Prof. A. M. Greene of Troy, Dean Perley F. Walker of Kansas, W. S. Lee of New York, American Society of Mechanical Engineers; Prof. Joseph W. Roe of New York, Society of Industrial Engineers; Morris L. Cooke, Philadelphia, Taylor Society.

Regional directors chosen for 1922 are: District 1, W. B. Powell, Buffalo; District 2, Gardner S. Williams, Ann Arbor, Mich.; District 4, W. J. Fisher, York, Pa.; District 5, Paul Wright, Birmingham, Ala.; District 6, Lloyd B. Smith, Topeka, Kansas; District 7, O. H. Koch, Dallas, Texas.

Membership

The Secretary's report showed that on January 1, 1921, the membership of the society was composed of six national and fourteen state and local societies—a total of 20; whereas, on December 31, 1921, there were eight national and twenty state and local societies—a gain of eight member societies during the year, with an aggregate membership of 1414 individuals.

The Engineers Club of Columbus, Ohio, was admitted to membership at the meeting, and there are now more than twenty active prospective member societies.

Regular Meetings

The Council adopted an amendment to the by-laws providing that the Executive Board shall hold a meeting at the close of the Annual Meeting of the Council, at which time it shall organize and fix and announce a schedule of regular meetings for the ensuing year. The Executive Board under this authority voted to hold five meetings—two in connection with the meetings of the Council.

Patent Office Legislation

The Council voted to continue support of the proposed legislation for the relief of the United States Patent Office, as embodied in the Lampert Bill. The report of the Council's Patent Committee, headed by Edwin J. Prindle of New York, described conditions in the Patent Office as alarming. (Since the meeting of the Council the Lampert Bill has passed the House of Representatives.)

Resolution Adopted

The following resolution expressing the appreciation of the services of Herbert Hoover, first President of the Council, was unanimously adopted:

WHEREAS our first President, Herbert Hoover, has been appointed Secretary of Commerce in the Cabinet of the President of the United States and

WHEREAS, in consequence of his acceptance of this high public office, he deemed it necessary to tender his resignation as President of the Federated American Engineering Societies,

BE IT THEREFORE RESOLVED by American Engineering Council, that we hereby record our appreciation of the rare judgment and vision with which Mr. Hoover has directed the initial policies of The Federated American Engineering Societies, and the ability and uniform courtesy with which he has presided over the deliberation of the Council and of the Executive Board

BE IT FURTHER RESOLVED that American Engineering Council acting through its Executive Board express to him the sincere regret with which his resignation has been accepted and its sincere good wishes for a continuation of that distinguished success which has followed him in his past services to his profession, his country and mankind.

Licensing of Engineers

There was a long discussion upon the question: "Does the American Engineering Council approve or disapprove of the principle of licensing or registering of engineers?" Laws are already in force providing for licensing or registering in many of the states, and similar legislation is being advocated in many other states. At the close of the discussion the President was authorized to refer the whole subject to a committee for the purpose of making a thorough study of the question, including the advantages and disadvantages as found in the states in which legislation upon the subject is already in effect.

New Publication Proposed

There was considerable discussion on a suggestion to establish some form of periodical for the purpose of keeping members of the various societies represented in the Federation informed regarding matters of interest to the profession. During the discussion it was pointed out that the larger societies had their own publications and were always glad to give publicity to the work and activities of the Federation. The demand for a separate publication was principally voiced by representatives of local organizations which have no publications of their own. It was suggested that probably the continuation or slight modification of the present small mimeographed bulletin would meet the needs of these members. The Publicity Committee made no recommendation and the Council referred the matter to the Executive Committee for further consideration.

Government Economy Endorsed

The Council passed a resolution prepared by J. Parke Channing of New York, chairman of the Council's Committee on Public Affairs, commending Gov. Miller for urging the elimination of unnecessary duplication of effort between the New York State Department of Public Works, the State Engineers' office the Department of Highways, the State Architect and the Department of Public Buildings.

The Council expressed sympathy with Gov. Miller's proposal, that the activities of these agencies should be coordinated, and offered to the Governor the services of its Committee on New York State Government Reorganization in the carrying out of an effective coordination plan. The Council's action was unanimous.

Dinner at University Club

On Thursday evening, January 5th, the members present attended a dinner at the University Club. President Cooley acted as Toastmaster and addresses were made by Honorable Herbert Hoover, Dr. B. Stepanek, Minister from Czecho-Slovakia to the United States, and Mr. John Temple Graves.

Dr. Stepanek expressed during his address appreciation of the fact that the American Engineering Council had granted his government copyright privileges on the Report of the Committee on Elimination of Waste in Industry, and stated that the report had already been translated and published in his country.

Herbert Hoover's address is given in part below.

Address by Herbert Hoover

Fellow engineers: I did not come prepared with any large and efficient words of wisdom and have been rather fearful that I did not sit down in Council with your directors and develop something.

I am interested in this association not only because I participated, I do not put it higher, in the organization of the Council, but because this body has entered upon a path of public service that is unique in the whole United States.

I have perhaps said before in urging some of our brother societies to join with the Council, that the engineer has devoted himself all these years to the upbuilding of the material values of the United States. He has done that effectively—more effectively than has been accomplished in any other of the great countries of the world.

The birth of this society marks the evolution of the engineer into an interest in public affairs. With his intelligence, his experience and training and the unique knowledge that he possesses not only of the material but the intangible values amongst our people, he is now organized so that his united voice may become heard outside of his profession.

We have probably 175,000 engineers in our country, representing an intellectual possibility for service possessed by no other group. It is therefore an augury of real social development when the engineers of the United States join together for purposes of public service.

This association has the unique value among the associations that it can not have any material interest for its purpose. No engineer can receive any material benefit from it. It can advance no economic interest. It can not therefore be charged with any ulterior motive. It is accepted by the whole American people who have become acquainted with its objectives as being clearly single-minded.

During the last year we considered a number of the problems that confront the American people in the light of what services the engineers could perform in their solution. We resolved early in the progress of the Council to undertake an investigation into the elimination of waste— a problem with which the engineer alone was fitted to deal, a problem that had not come in for solution outside of engineering circles.

As a result of the investigation carried on during the past year and of the report made there has been an enormous expansion of the consideration of these fundamental questions—questions that enter into the whole problem of the standard of living of our people. At the time we undertook that investigation we were still at the height of a boom. The country was going on recklessly spending, with extravagance and over-expansion. Almost every engineer in consideration of the economic situation of the time and the early meetings of the Council wondered when it would all come to an end and appreciated the waste that came from the operation of the business cycle, which reaches its peak in booms like that then affecting the country. That investigation resulted in a final report in the midst of the depression that was inevitable. It came just at a time when the country was receptive for ideas that in the long run must mean the correction of these tremendous losses from over-expansion and from depression.

On taking this position that I now hold I had felt that it was the duty of the Government, if it was possible, to carry into effect some of the purposes outlined by the Council. We have in the Department of Commerce, accordingly, established a number of agencies intended to effect the results outlined as possible. And in getting further knowledge and experience with this problem I am indeed impressed with the fact that it is the most fundamental of all of the economic problems with which the American people must deal. It becomes doubly important now because we are faced with certain primary conditions that can not, in my view, receive any solution except along the lines laid down in that report on the elimination of waste.

If we take the year 1913 as a base year for economic calculation and assume that the price of goods to the producer was 100 and likewise the cost to the consumer was 100, and if we then examine the situation today we will find that in many, in fact the majority of cases, the value of commodities is not far from 100 in their return to the producer and, more particularly, we will find the agricultural products often far below that level. But, on the other hand, to the consumer, the price level is, in the majority of cases, from 150 to 170.

We have therefore, a tremendous distortion. That distortion bears heavily on the producer and the consumer. One or the other of the two must carry the brunt of that load. And if we are to decrease that margin, it can only be through the elimination of waste.

We have to bear in mind that during these last seven years we have probably added eight billions per annum to National, State, and municipal taxation.

If, on the basis of the present value of the dollar, we estimate that the National productivity of the country is somewhere near fifty billions, it is possible to calculate at once that taxation alone accounts for at least twenty units out of the sixty or seventy with which we have to deal.

There are other elements that have entered into the problem—increased cost of transportation and a thousand direct or indirect increases in the cost of manufacture or distribution.

And, clearly, unless we can bring the cost of commodities to the consumer more nearly into line with the return to the producer, we shall indeed to go no further, reduce our agricultural population to the status of the European peasant.

That is a problem of manufacture, transportation, and distribution. The distortion is not due to undue profits at the present time. It is distortion that can be corrected only through the elimination of wastes in our processes of distribution and other phases—transportation, business methods, manufacture, and so on. Indeed the question of the elimination of waste entered into two years ago because of those glaring outstanding instances that challenged every engineer now looms in the mind of every economist as the real hope of reestablishing economic balance in the United States.

We have enlarged our vision as to what constitutes waste. We are suffering today from one of the most fearful wastes that can come to us in that we have from two to three millions of idle men.

Lost labor once over the dam is lost for all time.

Any inquiry into the causes of our vast unemployment brings us at once to consideration not alone of the world as a whole and of our own economic cycle in relation to it but also to the problem of how to avoid such periods of waste.

Now, the engineers have rightly pointed out that there are times when we make large increases both in the direction of plant and equipment and in production of consumable commodities; that if we are to correct and alleviate the intensity of our business

cycles, we must find some method by which we can expand our plants and equipment at periods when the demand for consumable goods has relaxed. Nor is that a misconception. For if we were to hold over a part of our seasonal operations on great public utilities and public works through periods of from seven to ten years, a reserve of probably no more than ten per cent stored up for periods of depression in the production of consumable goods would enable us to maintain an even tenor and to secure even production of all commodities.

There lies one of the greatest wastes and it is in the anticipation of that waste where lies one of the great economic problems of the country.

There are many ramifications of the waste problem which you are familiar with—many, more familiar than I am. But there is one factor in the saving of waste to which I believe the engineers might give further consideration and perhaps more investigation. And that is the problem of a larger view in electrification.

We are all aware of the results obtained in the investigation of the superpower development of the Atlantic seaboard. Superpower is not impossible in many other sections of the country. We are indeed on the threshold of enlarging the distances of transmission. We have the possibility of reducing waste through a large phase of electrical development made during the past thirty years. The American people have no appreciation of the possible results and the added efficiency, productivity, safety and advance that could be obtained in the enlargement of our entire electrical equipment. And there is no body that could give this problem such consideration and so illuminate it in the National sense as this Council could do. It indeed requires the services of every branch of engineers that compose the Council. With the possibility ahead of us of the development of some twelve to fifteen millions of horse power, the consolidation of hundreds, even thousands of minor plants, the enormous savings to be made through the substitution of electrical power for steam—in that there is a probablity of the greatest material saving of waste possible in any country, in front of the American people.

Now, it is one thing to suggest a problem and another thing to suggest its solution. It is a far more difficult thing to state a problem in a fashion that people will understand and state its solution in a fashion that will carry conviction. But an association of this kind, ramifying as it does into the best intelligence of every single community of the United States, has the opportunity to develop popular conception of its ideas more effectively than any other group in the country.

Still, I am not attempting to outline to you the services that you can undertake for you have on your docket a long list of matters which must be given study and advancement. We recognize the necessity of cohesion among the engineers. The objectives of the Council can be phrased in the common language of the great visions of engineers in the direction of the services they can perform for their communities. And in the contact of engineers with the public life of the Nation there is no possibility of overlapping in the technical services of our member societies.

It is not alone a problem for your directors that the engineers should be reported in the public councils of the Nation but it is a problem of inspiring the same attitude of mind amongst the engineers in every city, town, and village in the United States. There is no State or city or municipal government that does not need the advice of the Engineering Council. There is no problem either in Federal or State or municipal legislation that does not at some point touch upon material construction and therefore come within the purview of the engineer. So that while the Council here in Washington and in those centers where the directors can keep in contact with needs and the problems in hand does a great service, the same opportunity and the same need exist throughout the country.

I know of no way of inspiring service except by contact.

That service the country needs.

It needs the plans and the intelligence of its engineers—the men who have in the very nature of their work the inspiration and enthusiasm and yet are the greatest realists in the world—and they are the men who should be heard from.

For the service you have done during the past year is small measure of what can and will be accomplished by you, through the Council.

Associated Technical Societies of Detroit Founded

After several years of thought and discussion along similar lines, the movement for the affiliation of the architectural, engineering and other technical societies of Detroit was taken up seriously in June 1921 by the organization of a Temporary Council composed of two delegates from each of the several societies interested. The affiliation has become an accomplished fact, taking effect January 1, 1922, by the ratification of the proposed Constitution and By-Laws, acceptance of membership and election of Counc llors by the following twelve societies: Detroit Section, American Society of Civil Engineers; Detroit Chapter, American Association of Engineers; Michigan Chapter, American Society of Heating and Ventilating Engineers; Detroit Post, Society of American Military Engineers; Detroit Section, American Society of Mechanical Engineers; Detroit-Ann Arbor Section, American Institute of Electrical Engineers; American Institute of Chemical Engineers; Detroit Engineering Society; American Chemical Society and Detroit Chemists; Michigan Chapter, American Institute of Architects; Detroit Section, Michigan Society of Architects; Detroit Chapter, American Society of Steel Treating.

The permanent Council met and organized December 13, 1921 and elected officers for 1922 as follows: Chairman, P. W. Keating; Vice-Chairman, A. A. Meyer; Secretary-Treasurer, Walter R. Meier.

The engineers, architects, chemists and other technical men of Detroit have for some time appreciated the need of one central association to represent the combined interests of these professional men. A central office will be established for conducting the business of the several societies. In the past, each of the several societies held a number of meetings throughout the year. Most of the societies met regularly once a month and some of them two and three times a month. The meetings of the various societies have often occurred on the same date but this conflict of dates will hereafter be avoided as the office of the new association will schedule the dates of meetings of all the technical societies. The Associated Technical Societies of Detroit will provide one meeting each month and this meeting will be under the management of one of the member societies. This member society will provide the speaker on a broad subject of interest to the members of all the technical societies.

The paramount use of the new association to its members and to the public is its opportunity for public service both for the city of Detroit and for the state of Michigan. The association will take an active interest in all matters wherein engineering, architectural and technical subjects are an important factor. The Council will study the opinions of the membership and will assist in furnish ng definite and accurate information to the public. The association will offer its assistance and advice to city and state officials whenever required. The aim and purpose of these activities will be to provide the highest and most reliable technical information for the proper consideration of public improvements and public undertakings in which all our citizens are interested.

A. I. E. E. Section in Santiago, Chile

Under date of November 23, members of the Institute located in Santiago de Chile forwarded a petition to Institute headquarters requesting authority to organize a Section of the In-

stitute, to comprise the territory within the Republic of Chile. This petition was approved by the chairman of the Sections Committee and the desired authority was granted by the Executive Committee at a meeting held in New York, January 13.

In a letter transmitting the petition on behalf of the members located in Chile, Mr. R. F. Hayward, who for many months was one of the most active members of the Vancouver Section and who removed to Santiago in the Fall of 1920, said: "There is great electrical activity in Santiago, Valparaiso, and the surrounding districts. The state railways between Santiago and Valparaiso are being electrified and there is a probability of the electrification of the Transandine Railway. The University of Chile is an old and very well established organization, with a strong engineering department. In considering the present activities and the future developments, we believe the time is ripe for the establishment of a Section of the American Institute of Electrical Engineers."

Research Graduate Assistantships

ENGINEERING EXPERIMENT STATION, UNIVERSITY OF ILLINOIS

To assist in the conduct of engineering research and to extend and strengthen the field of its graduate work in engineering, the University of Illinois maintains fourteen Research Graduate Assistantships in the Engineering Experiment Station. Two other such assistantships have been established under the patronage of the Illinois Gas Association. These assistantships, for each of which there is an annual stipend of $600 and freedom from all fees except the matriculation and diploma fees, are open to graduates of approved American and foreign universities and technical schools who are prepared to undertake graduate study in engineering, physics, or applied chemistry.

An appointment to the position of Research Graduate Assistant is made and must be accepted for two consecutive collegiate years, at the expiration of which period, if all requirements have been met, the degree of Master of Science will be conferred. Not more than half of the time of a Research Graduate Assistant is required in connection with the work of the department to which he is assigned, the remainder being available for graduate study.

Nominations to these positions, accompanied by assignments to special departments of the Engineering Experiment Station, are made from applications received by the Director of the Station each year not later than the first day of March. The nominations are made by the Executive Staff of the Station, subject to the approval of the President of the University. Nominations are based upon the character, scholastic attainments, and promise of success in the principal line of study or research to which the candidate proposes to devote himself. Preference is given those applicants who have had some practical engineering experience following the completion of their undergraduate work. Appointments are made in the spring, and they become effective the first day of the following September. Vacancies may be filled by similar nominations and appointments at other times.

Additional information may be obtained by addressing The Director, Engineering Experiment Station, University of Illinois, Urbana, Illinois.

Illumination Items

NEW ACTIVITIES OF LIGHTING AND ILLUMINATION COMMITTEE

At a recent meeting of the Lighting and Illumination Committee of the A. I. E. E., it was decided to furnish the JOURNAL with lighting information of news interest to the members of the Institute. In accordance with this plan the first contribution appears in this issue on page 149. The committee expects to establish a monthly review of important developments and general information in the lighting field.

Mr. W. M. Skiff, Nela Park, Cleveland, O., has been designated by the committee to take charge of this activity. He will welcome suggestions, comments and appropriate contributions.

The Lighting and Illumination Committee stands ready to assist Sections and Branches of the Institute by suggesting topics and speakers for meetings and by aiding in these arrangements as far as practicable. Requests should be addressed to the chairman, G. H. Stickney, 5th and Sussex Streets, Harrison, N. J.

PERSONAL MENTION

PAUL LIUNGE, of the engineering department of the New York Edison Company, has sailed for Denmark for several months' stay.

A. H. SWEETMAN, until recently with Stone & Webster, Boston, is now located with the Edison Electric Illuminating Company of Boston.

A. D. SHULTZ has left the Eastern Shore Gas & Electric Company, Salisbury, Md., to become connected with the L. J. Marsh Electric Company of Philadelphia.

GUY K. CALHOUN, formerly in the Bureau of Steam Engineering, Navy Department, Washington, has taken up work with the Sperry Gyroscope Company, Brooklyn, N. Y.

J. D. WHITEMORE, until recently with the West Virginia Traction & Electric Company, Wheeling, W. Va., is located with the West Penn Power Company, Pittsburgh.

G. S. NUNEMAKER, formerly general superintendent of the Tennessee Power Company, Chattanooga, Tenn., has become general manager of the Cumberland Power Company, Lebanon, Tenn.

D. C. DURLAND has severed his connections with the Mitchell Motors Company, Racine, Wis., of which he was president and general manager, and is located with the General Electric Company, New York City.

FRANK J. BEAVERS, formerly distribution engineer with the Gary Heat, Light and Water Company, Gary, Ind., is now located with the engineering department of the Scranton Electric Company, Scranton, Pa.

F. D. EMORY becomes on February 1st superintendent of operation and maintenance, B. C. & Alberta Power Company, Ltd., Fernie, B. C., Canada. He was previously district inspector in the electricity and gas departments, Nelson, B. C.

ERNEST V. PANNELL, of the British Aluminum Company, Ltd., New York City, will represent that company in Tokyo, Japan, after February 1st. His address there will be c/o Furukawa & Company, Tokyo.

R. L. BOISEN, until recently with the Ironwood & Bessemer Railway & Light Company, Ironwood, Mich., as superintendent, street railway, has left to become connected with the Ashland Light, Power & Street Railway Company, Ashland, Wis.

EARL E. NORMAN has accepted appointment as director of the Department of Public Utilities, City of Kalamazoo, Mich. He was formerly with the General Electric Company, Atlanta, Ga.

E. C. GEITHER has been appointed manager of the Ingersoll Rand Company of New England, in Boston. He was previously assistant general sales manager of the Ingersoll Rand Company, New York City.

ERNEST G. B. MILLAR has become chief engineer of the English Electric Company of Australia, located in Sydney. He has been for several years designing engineer for the G. Weymouth Electric Company, Richmond, Victoria.

F. E. Galbraith, division superintendent of line construction with the American Telephone & Telegraph Company, has left the New York office of the company and is located in Philadelphia. His connections with the company remain the same.

C. L. Stone has left the Southern New York Power & Railway Corporation, Cooperstown, N. Y., of which he was vice-president and general manager, to become connected with the Cleveland Electric Illuminating Company, Cleveland, Ohio.

Carleton H. Parker is now located with the United Electric Railways Company, Providence, R. I., in the line and signal department. He was previously with the Puget Sound Telephone Company, Everett, Wash.

Charles Matthews, chief electrician of the Curry Camping Company, Yosemite Valley, Cal., will commence for his company on March 1 the installation of one of the largest electric cooking equipments in the United States. The installation will be of 350-kw. capacity, 220 volts.

Lyle A. Whitsit is now located with the Adirondack Light & Power Corporation, Amsterdam, N. Y., as hydroelectric engineer. Mr. Whitsit was an engineer with the Superpower Survey of the U. S. Geological Survey, which was located in New York under the direction of W. S. Murray in 1920 and 1921.

W. M. Vernor will soon leave for the Philippines to take up work as electrical engineer and salesman with the Catton-Neill Engineering and Machinery Company, Manila. He was formerly employed with the Westinghouse Electric & Manufacturing Company, New York City.

W. H. Patterson, who has been assistant manager of the industrial department of the Westinghouse Electric & Manufacturing Company, E. Pittsburgh, has resigned to accept the position of vice-president of the Kaestner & Hecht Company, Chicago, elevator manufacturers.

Albert T. Westrap, who has been with the British Thomson-Houston Company, has left England for India, where he will be engaged on the Cauvery Power Scheme, Sivasamudram, Mysore State. Mr. Westrap has assisted in several installations of the hydroelectric plant at Cauvery Falls at various times.

Carl G. Schluederberg, assistant manager of the supply department of the Westinghouse Electric & Manufacturing Company, E. Pittsburgh, left recently for South America, where he will spend three months visiting Chile, Peru, Uruguay, Paraguay and Brazil, studying electrical merchandising business conditions in the interest of his company.

D. M. Fraser has severed his connections with the Canadian General Electrical Company, Ltd., and is now president of the Dominion Engineering Agency, Ltd., Toronto. Mr. Fraser is a graduate of Heriot-Watt College, Edinburgh, and has had a number of years of broad electrical engineering experience in Scotland, England and Canada. He has served as secretary of the Toronto Section of the Institute.

G. G. Thompson, for the past ten years with the Cutler-Hammer Manufacturing Company, has recently become connected with the Ward Leonard Electric Company, Mount Vernon, N. Y., where he will specialize on magnetic theater dimmers. Mr. Thompson is a graduate of the University of Michigan and has had twelve years' experience in the design of electric control apparatus and resistors.

F. M. Feiker, vice-president of the McGraw-Hill Publishing Company, who for the past eight months has been a special administrative assistant to Secretary of Commerce Hoover in the reorganization of the Department of Commerce, has resigned, but will continue his relations with the department in a consulting capacity. Mr. Feiker has been on leave of absence from the McGraw-Hill Company in order to give his services to the Department of Commerce.

William I. Whitefield, for the past seven years connected with the Roanoke Railway & Electric Company, Roanoke, Va., as power salesman and assistant superintendent, lighting and power department, has accepted a position with the Chas. M. Kelso Company, engineers and contractors, and will be located at Utica, N. Y., after March 1, 1922. Mr. Whitefield is a graduate of the Virginia Military Institute and a certified professional engineer in the State of Virginia.

Clarence P. Fowler, consulting engineer for Graham, Parson & Company, investment bankers, Philadelphia, recently delivered a series of addresses to the sales organization of that firm, on the elements determining the safety of principal and interest of investment securities based upon the different classifications of public utility and industrial enterprises. Mr. Fowler has had extensive experience in the construction and management of properties in practically all parts of the United States and Canada, many of which he has examined and reported upon to investment banking houses for financing purposes.

V. A. Zehr, consulting engineer of Pekin, Ill., who sailed last August for Europe to investigate a construction work near Prague, Bohemia, has located in Brandys Labe, Czechoslovakia, where he will practise engineering. Mr. Zehr was born in Brandys, attending school in Prague, and after several years of practical engineering experience came to this country in 1915. Here he was employed successively with Stone & Webster, Boston, General Electric Company, Schenectady, Westinghouse Electric & Manufacturing Company, E. Pittsburgh and E. T. Perkins Engineering Company, Chicago, after which he opened his own office in Pekin, Ill.

C. W. Parks, Rear Admiral, Chief of Civil Engineers, U. S. N., resigned his position as chief of the Bureau of Yards and Docks, Washington, D. C., on December 15 last, and has been placed on the retired list. Rear Admiral Parks joined the Institute in 1887, at which time he was head of the physics department of Rensselaer Polytechnic Institute. He has held various engineering positions since entering the U. S. Navy; previous to the office in Washington from which he has just retired he was for several years public works officer of the U. S. Navy Yard in Philadelphia, and then held the same title at the U. S. Naval Station in Pearl Harbor, Hawaii.

Eric A. Lof, industrial engineer and specialist of the power and mining engineering department of the General Electric Company, was recently the recipient of a medal conferred on him by the King of Sweden, in recognition of meritorious services to the Swedish government. Mr. Lof was born in Sweden and came to this country in 1902, becoming connected with the General Electric Company at Schenectady in 1909. Last year he spent several months in Europe for the International General Electric Company, partly in connection with the extensive power transmission and railway electrification projects which are being planned by the Swedish government. Mr. Lof is the author of several books and of a number of contributions to the technical press, and has also delivered lectures on various subjects.

Obituary

Wm. F. Doherty, of Bombay, India, was murdered in Bombay by Indian rioters on November 19, 1921. Mr. Doherty with his wife had attended various functions held in connection with the visit of the Prince of Wales, and on the morning of the 19th left for Byculla to see about some repairs for the Bombay Building Supply Company, of which he was part owner. He had received no warning of any danger, but on the way was waylaid by a mob of rioters and murdered. Mr. Doherty was an American, born in Bentonville, Arkansas, in 1881. He was a graduate of the University of Nevada. After a number of years of engineering experience with various companies in this country, including a year as chief engineer in charge of the El

Paso Milling Company, El Paso, Tex., he went to Spain in 1913 to take full charge of the installation of equipment in the Pobla hydroelectric station. After nearly two years there he left for Cuba, where he was assistant chief electrical engineer with the Cuban American Sugar Company. Several years later he became connected with the Tata Hydroelectric Power Supply Company, Bombay, as chief engineer of generation, which position he held until 1921, leaving in order to devote his time to the Bombay Building Supply Company. This company was originated through a new process invented by Mr. Doherty for the excavation of sand shingle from beneath 15 to 20 feet of water. The company is contractor to the government. Mr. Doherty became a Member of the Institute early in 1919.

Llewelyn Owen. Word has been received of the death of Llewelyn Owen, a Member of the Institute, on August 21, 1921. Mr. Owen was superintendent of the electrical department of the Central Illinois Light Company, Peoria, Ill. He started with this company in 1899, when it was known as the Peoples Gas and Electric Company, and was at that time assistant superintendent of the company. As the company developed he became assistant superintendent of the electrical department, and in 1907 was appointed superintendent of this department, which position he held at the time of his death. Mr. Owen was born in Milwaukee, Wis., in 1876, and was graduated in electrical engineering from the University of Wisconsin.

Edward S. Morrell, assistant superintendent in charge of electrical and mechanical equipment of the general office buildings of the Pennsylvania Railroad Company, Philadelphia, died on December 24, 1921. Mr. Morrell was born in Philadelphia in 1870, and had been associated with the electrical contracting and engineering business for a number of years, installing and designing lighting and power plants throughout the country. In 1904 he became assistant electrical engineer with the Pennsylvania Railroad Company, later appointed electrical engineer. He joined the Institute in 1917.

N. A. Wolfe of the industrial control engineering department of the General Electric Company, Schenectady, N. Y., died December 16, 1921, from general meningitis. He was ill just a week. Born in Wheeling, W. Va., in 1885, Mr. Wolfe was graduated from the University of West Virginia in 1910. He then entered the testing department of the General Electric Company at Schenectady, and remained with that company in various departments to the time of his death. In 1911 he joined the Schenectady Section of the Institute, and in 1917 became an Associate of the Institute.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

LIBRARY BOOK LOANS

The Library Board of the Engineering Societies Library has adopted rules authorizing the Director of the Library to lend to members of any Founder Society any duplicate books in the library, subject to the following rules:

1. Duplicate books may be lent to members of Founder Societies or of any other societies that contribute to maintain the Library.

2. Books will be lent for twenty-eight days, including time in transit.

3. Five cents a day will be charged for each book kept longer than twenty-eight days.

4. Borrowers shall be responsible for books borrowed, and shall pay shipping and insurance charges from and to the Library.

The Library has several thousand volumes that can be lent under this authorization. These include a considerable number of text-books, reports, etc. of various dates. Periodicals are not included, as the cost of storing duplicate sets seems prohibitive and individual articles can be photoprinted at little expense. The collection is being increased regularly by the addition of any suitable duplicates received by the Library. Members are invited to present any books of permanent value for this purpose, which they can spare from their libraries. It is hoped that the collection may in time become adequate to meet the usual needs of members by providing any standard book needed for a short time.

No catalog has been published, although it is hoped that one may be, when the collection becomes extensive enough to warrant doing so. Until that time, the Director will be glad to receive requests and report whether the books are available or not.

BOOK NOTICES (DEC. 1-31, 1921)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

Radioactivity and Radioactive Substances.

By J. Chadwick. Lond. and N. Y., Sir Isaac Pitman & Sons, Ltd., 1921. (Technical primers). 111 pp., illus., 6 x 4 in., cloth. $.85.

This clear, accurate account of radioactive phenomena, by one with first hand knowledge of the facts, furnishes the beginner with a simple, concise, accurate introduction to the subject.

Radio Questions and Answers.

By Arthur R. Nilson. First edition. N. Y. & Lond., McGraw-Hill Book Co., Inc., 1921. 86 pp., illus., 7 x 5 in., boards. $1.00.

A quiz compend for those preparing for examinations. Treats of theory, apparatus, laws and regulations, etc.

EMISSION OF ELECTRICITY FROM HOT BODIES.

By O. W. Richardson. Second edition. Lond. and N. Y., Longmans, Green and Co., 1921. (Monographs on physics.) 320 pp., 9 x 6 in., cloth. $5.25.

This work, one of a series of monographs in physics editep by Sir J. J. Thomson and Prof. Horton, deals with the emission of positive and negative electricity from hot bodies. The author was one of the first investigators of this subject and a large part of our knowledge is due to his work. As a consequence we have a clear, up-to-date account of the subject written by one who appreciates fully the experimental difficulties and the adequacy of the theories proposed. This edition has been extended and thoroughly revised.

MEMOIRS SUR L'ELECTROMAGNETISME ET L'ELECTRODYNAMIQUE.

By Andre-Maries Ampere. 110 pp., illus., 7 x 4 in., paper. 3 frs.

The two classic memoirs in this little book are that in which Ampere described his experiments upon the action exerted on an electric current by another current or a magnet, and the one giving the results of his study of the formula expressing the attraction and repulsion between two infinitely small elements of two conductors. They are here reprinted from the best text in attractive form.

TURBINES.

By A. E. Tompkins. Third edition, revised. Lond., Society for Promoting Christian Knowledge; N. Y., The Macmillan Co., 1921. 180 pp., illus., 8 x 5 in., cloth. $2.50.

Describes in simple non-mathematical fashion, good modern practise in the construction and working arrangement of water turbines, turbine pumps and steam turbines. Useful to students and to men engaged in fitting and repairing turbines.

ELEMENTS OF ILLUMINATING ENGINEERING.

By A. P. Trotter. Lond. and N. Y., Sir Isaac Pitman & Sons, Ltd., 1921. (Technical primers.) 103 pp., illus., 6 x 4 in., cloth. $.85.

This primer, intended as an introduction to the elements of the subject, gives a clear concise account of the theoretical principles, and of modern practise in the distribution and measurement of illumination.

TREATISE ON THE INTEGRAL CALCULUS.

By Joseph Edwards. Vol. 1. Lond., Macmillan and Co., Ltd., 1921. 907 pp., 9 x 6 in., cloth. $16.00. (Gift of the Macmillan Co., N. Y.)

The first volume of an extensive treatise on the subject for advanced students. Attempts to collect all the information necessary to give the reader a good working knowledge of integral calculus, both practically and theoretically, and to place this information before him as clearly as possible, with abundance of illustrative examples and instances of the application of the principles explained.

GRAPHICAL ANALYSIS: A TEXT-BOOK ON GRAPHIC STATICS.

By William S. Wolf. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1921. 374 pp., illus., 9 x 6 in., cloth. $4.00.

Based on the author's courses in the University of Illinois. Deals with the analysis of stresses rather than with design or the computation of loads, but includes some consideration of these questions also.

COURS DE MECANIQUE RATIONELLE.

By Louis Roy. Paris, Gauthier-Villars et Cie, 1921. 259 pp., 10 x 6 in., paper.

This volume with the author's previous book on graphic statics and strength of materials forms a course of instruction in mechanics for students of engineering. The present work is intended for beginners and therefore is confined to the elements of mechanics, which it presents so that students will have the grounding necessary for the study of applied mechanics, general physics and electrical engineering.

LA PHYSIQUE THEORIQUE NOUVELLE.

By Julien Pacotte. Paris, Gauthier-Villars et Cie, 1921. 182 pp., 10 x 6 in., paper. 12 fr.

The new physics in question had its origin in Lorentz's electrodynamics, which is the definitive form of Maxwell's theory; its most advanced theories are due to Einstein; it has to do with relativity, with the energy equivalent of two masses of matter, with atoms of energy.

The author presents a historical critical, non-mathematical account of the theories that underlie modern ideas suitable as an introduction to the subject.

ESSAI PHILOSOPHIQUE SUR LES PROBABILITIES.

By Pierre-Simon Laplace. Paris, Gauthier-Villars et Cie, 1921. (Maitres de la pensee scientifique.) 2 vol. 7 x 4 in., paper. 3 fr. per vol.

In this famous book Laplace presented, without resorting to analysis, the principles and general results of the theory of probabilities, and applied them to some of the most important questions of life. The present edition reproduces the best text in a cheap, convenient edition.

LA LOI DE NEWTON EST LA LOI UNIQUE.

By Max Franck. Paris, Gauthier-Villars et Cie, 1921. 158 pp., 10 x 6 in. paper. 12.50 fr.

The question considered in this book is whether it is possible, with our present knowledge, to formulate the law governing the mechanism of the universe. Upon two postulates, that all potential energy resides in the absolute space of the physicist, and that all matter is formed of an element of inertia movable in space, the author erects a hypothesis, and compares its consequences with known facts, to determine how nearly the two agree.

The first consequence is the confirmation of Newton's law, which may now be given its exact intrepretation; this is the reason for the title given the book. The author's theory uses only the notions of space, time force and inertia admitted in Euclidean geometry and mechanics.

ECONOMICS OF PETROLEUM.

By Joseph E. Pogue. N. Y., John Wiley & Sons., Inc.; Lond., Chapman & Hall, Ltd., 1921. 375 pp., plates, illus., 9 x 6 in cloth. $6.00.

The purpose of this book is to present the more important economic facts relating to petroleum, to interpret the changes that are taking place in the industry and to forecast the future trend of these changes. The book is intended for those engaged in the petroleum industry as engineers or producers, and for those engaged in industries dependent on petroleum products, and contains useful information on our resources, the trend of development, production and refining, transportation, prices, trend of consumption, and similar topics.

MATERIAL HANDLING CYCLOPAEDIA.

Compiled and edited by Roy V. Wright, John G. Little and Robert C. Augur. N. Y. Simmons-Boardmann Publishing Co., 1921. 846 pp., illus., 12 x 9 in., cloth. $10.00.

Designed to present comprehensively definitions, descriptions, illustrations, applications and methods of operation of industrial devices for handling materials. Covers hoisting machinery, package conveyers, loose material conveyers, elevators, trackless transportation, industrial rail transportation and handling systems. Each section has been prepared by a specialist.

Addresses Wanted

A list of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

1.—Waldo C. Cole, 410 Mills Bldg., El Paso, Texas.
2.—E. W. Erikson, 214 University Club Bldg., St. Louis, Mo.
3.—E. L. Neil, Box 401, Palo Alto, Calif.
4.—Frank J. Quinn, Lord Electric Co., 105 W. 40th St., New York, N. Y.
5.—R. W. Seem, 633 W. 74th St., Los Angeles, Calif.
6.—F. W. Smith, 500 Todd St., Wilkinsburg, Pa.
7.—Frank Spiruta, 1402 So. 61st Ave., Cicero, Ill.
8.—Louis H. Wessels, 105 Union St., Jersey City, N. J.

Past Section and Branch Meetings

SECTION MEETINGS

Atlanta.—December 29, 1921, Assembly Hall, Chamber of Commerce Building. Subject: "Muscle Shoals" (illustrated by hydrographic charts and blueprints). Speaker: Mr. Charles G. Adsit, of the Georgia Railway and Power Company. Following this talk Mr. L. E. Lewis, who was in charge of a portion of construction work when Muscle Shoals Plant was being constructed, delivered a very interesting paper on the general arrangement and the processes which the Government had contemplated. Mr. A. M. Schoen gave a brief and interesting talk on some investigations which he recently conducted at the Wilmington works of the E. I. duPont de Nemours Company. Attendance 100.

Baltimore.—December 16, 1921, Service Building of the Westport Generating Station of the Consolidated Gas, Electric Light & Power Company. Members of the Baltimore Section of the A. S. M. E. and Johns Hopkins Electrical Club were present as guests. The meeting was preceded by an inspection trip through the generating station, after which a buffet supper was served in the cafeteria. Subjects presented: "The Design and Construction of the Westport Generating Station," by Mr. A. S. Loizeaux, of the Consolidated Gas, Electric Light & Power Company; "Operating Problems in the Westport Generating Station," by Mr. A. P. Penniman, Superintendent of Steam Stations of same company. Attendance 150.

Boston.—December 15, 1921, Walker Memorial Building, M. I. T. Joint meeting of the Boston Section A. I. E. E. and the combined professional societies of M. I. T. Subject: "Protection of Electric Systems." Speaker: Dr. Charles P. Steinmetz, Chief Consulting Engineer of the General Electric Company, Schenectady, N. Y. The talk was illustrated with lantern slides. Refreshments were served. Attendance 1100.

Chicago.—January 5, 1922. Western Society of Engineers Rooms. Joint meeting with the Western Society of Engineers and American Institute Mining and Metallurgical engineers. Subject. "The Story of Tungsten." Speaker: Dr. Balke, Chief Metallurgist of the Fansteel Products Company. Attendance 165.

Cincinnati.—January 3, 1922, Engineers Club of Dayton. Joint meeting of the Cincinnati Section A. I. E. E. and the Dayton Engineers Club. Subject: "The New Key of America's Development." Speaker: Dr. William McClellan, President of the A. I. E. E. This subject was enlarged upon by Dean Kimball of the College of Engineering Cornell University, and President of the A. S. M. E. Mr. C. F. Kettering, Vice-President of the Dayton Engineers Club also addressed the meeting. Attendance 190.

Connecticut.—December 15, 1921, Hartford Electric Light Company's Building. Subject: "Caribou Hydroelectric Development of the Great Western Power Company" (Feather River, Cal.) Speaker: Mr. Albert A. Northrop, Hydrualic Engineer, Stone & Webster Engineering Corporation, Boston. Attendance 175, including many members of the A. S. M. E. and A. S. C. E.

Denver.—December 12, 1921, Adams Hotel. Dinner preceded the meeting. Subject: "Colfax Station of the Duquesne Light Company of Pittsburgh." Speakers: Messrs. Charles W. E. Clarke and Don L. Galusha, of the Dwight P. Robinson Company. The talk was illustrated by moving pictures and lantern slides. Attendance 100.

Detroit-Ann Arbor.—December 9, 1921, Detroit Edison Company. Subjects: "Allied Interests of the Electrical Inspector and Electrical Engineer," by Mr. B. Clark; and "The Development of Insulation for Electric Wires," by Mr. Hugh T. Wreaks. Attendance 54.

Erie.—December 13, 1921. Joint meeting with Engineers Society of Northwestern Pennsylvania and Erie Section A. S. M. E. Subject: "Engines for Aeroplanes." Speaker: Major J. C. Riley. Attendance 200.

December 20, 1921. Public Library. Paper: "Biography of the Induction Motor." Author, Chairman Schum. Owing to the inability of Mr. Schum to be present, his paper was read by Mr. M. P. Anes. Attendance 20.

Ithaca.—December 9, 1921, Franklin Hall, Cornell University. Subject: "The Trend of Modern Physics as Related to Electrical Engineering." Speaker: Professor F. K. Richtmeyer, of Cornell University. Attendance 100.

Kansas City.—December 30, 1912, Blue Lantern Tea Room. Annual Meeting. Election of officers as follows: Chairman, C. J. Larsen; Secretary Glenn O. Brown. Subject: "Telephone Engineering." Speaker: Mr. H. C. Currier, of the Kellogg Switchboard and Supply Company. Attendance 20.

Los Angeles.—December 6, 1921, Lecture Room, Chamber of Commerce. Mr. A. C. McCune, of the American Welding Society, spoke of the advantages of the new organizations which are in process of formation through the country. A motion picture relating to the manufacture of iron and steel was shown, and the various steps explained by Mr. McCune. Mr. Cunningham of the General Electric Company showed some lantern slides relating to automatic welding equipment and automatic welding methods as used by the General Electric Company. Mr. Hopkins of the Westinghouse Company, also showed lantern slides of portable shop and stationary electrical welding equipment and gave examples of work accomplished with this apparatus. Attendance 100.

Lynn.—December 14, 1921, General Electric Hall, West Lynn. Joint meeting with Boston Section A. S. M. E. Subject: "The Development and Use of Precision Gages for Accuracy Determinations in Mechanical Measurements." Speaker: Major W. E. Hoke, Consulting Engineer of Baltimore, Md. The lecture was illustrated with lantern slides and also by the use of a large number of gages. Attendance 300.

January 4, 1922. Subject: "Banking." Speaker: Mr. J. D. Brennan, Vice-President, First National Bank, Boston, Mass. Refreshments were served at the close of the lecture. Attendance 175.

Minnesota.—December 14, 1921, Elks Club, St. Paul. Dinner was served preceding the meeting. Subjects: "Theory of the Vacuum Tube and Its Engineering Applications," by Professor C. M. Jansky, Jr.; "Wave Filters," by Professor R. R. Herrman. Attendance 42.

Panama.—November 27, 1921, Balboa Radio Station. Subject: "Radio Communication—Spark Telegraphy." Speaker: Mr. A. C. Bullock. Attendance 34.

December 18, 1921. Darien Radio Station. Subject. "Radio Communication—Arc Telegraphy." Speaker: Mr. A. C. Bullock. After presentation of the paper an inspection trip was made throughout Darien Radio Station. Attendance 38.

Philadelphia.—December 12, 1921, The Engineers Club. The meeting was preceded by a dinner. Subject: "The Steel Clad Rectifier." Speaker: Mr. J. H. Milliken, of the Mid-states Engineering Company, Chicago. Attendance 127.

December 20, 1921. Materials Handling Symposium. Joint meeting of Engineers Club of Philadelphia, Philadelphia Chamber of Commerce and the Philadelphia Sections of American Institute of Electrical Engineers, American Society of Civil

Engineers, American Society of Mechanical Engineers, Association of Iron & Steel Electrical Engineers, with the cooperation of Department of Wharves, Docks and Ferries, City of Philadelphia. *Afternoon:* "Yard Electrification of Industrial Plant Railways," by D. M. Petty, of the Bethlehem Steel Company, Bethlehem; "Design of a Port to Take Full Advantage of Mechanical Equipment," by Carroll R. Thompson, of the Department of Wharves, Docks and Ferries, City of Philadelphia; "What has been Done and What We Should Plan to do," by Col. Fred Jasperson, Assistant Chief Engineer, P. & R. Ry.; "What Can Be Done with the Ship's Gear," by Capt. S. C. Loveland, of the S. C. Loveland Company, Philadelphia. *Evening:* "Our plans for a Great Foreign Commerce," by Dr. Julius Klein, of the Bureau of Foreign and Domestic Commerce, Washington, D. C.; "Belt Line Railway at Philadelphia," by Hon. Geo. F. Sproule, Department of Wharves, Docks and Ferries, City of Philadelphia; Moving Pictures on "The Cost of Moving Material to and at a Pier," by Major Elihu C. Church, Transportation Engineer of the Port of New York. The evening session was preceded by a dinner in the Oak Room and South Tower of the Bellevue-Stratford Hotel. Attendance 300.

Pittsburgh.—December 19, 1921. Carnegie Institute of Technology. Subjects: "Radio Telephony and Broadcasting," by Mr. L. W. Chubb; "Broadcasting Transmitters," by Mr. D. G. Little; "Broadcasting Receivers," by Mr. M. C. Batsel, the three speakers being connected with the Westinghouse Electric & Mfg. Company. Preceding Mr. Batsel's talk a demonstration was given of standard radio receiving equipment with a cabinet graphaphone used as a loud speaker. A number of musical selections were listened to from Station K. D. K. A. Attendance 460.

Pittsfield.—December 15, 1921, G. E. Auditorium. Subject: "Radio Telephony." Speaker: Mr. B. R. Cummings, of the General Electric Company, Schenectady, N. Y. To illustrate the practicability of radio, a violin solo by Mr. Max G. Newman was received by a temporary improvised radio receiving set from Waconah Street, after which the audience listened to the tenor tones of Mr. James C. Morton. Mr. Herman L. West played the accompaniments. Attendance 350.

January 5, 1922, G. E. Auditorium. Subject: "Foreign Trade and Our International Relations." Speaker: Mr. Gerard Swope, President of the International General Electric Company. Attendance 250.

Portland.—December 14, 1921, University Club. Meeting held under the auspices of the Oregon Electrical Contractors and Dealers Association. Subjects: "History of the Contractor-Dealers Association," by Mr. John R. Tomlinson; "Interrelationship of the Contractor-Dealer and the Utility Company" by Mr. J. H. Sroufe; "The Possibility of Lengthening the Business Cycle," by Mr. Wm. D. Moriarty. Attendance 32.

Providence.—January 3, 1922, Providence Engineering Society's Rooms. Joint meeting of the Providence Section A. I. E. E. and the Power Section of the Providence Engineering Society. Subject: "The Initial Hydroelectric Development of the Belgian Congo." Speaker: Mr. William Frank Uhl. The talk was illustrated by lantern slides. Attendance 100.

St. Louis.—December 19, 1921, Century Electric Company. Election of officers as follows: Chairman, Mr. Charles C. Robinson; Secretary-Treasurer, Mr. J. M. Chandlee. Subject: "The Neutralized Series Conduction Motor on A-C. and D-C. Circuits." Speaker: Mr. Val A. Fynn. Attendance 25.

San Francisco.—December 9, 1921, Engineers Club. A symposium of papers on Industrial Electric Heating was presented as follows: "Pacific Coast Factory Conditions and Their Relation to Industrial Heating," by Mr. L. F. Leurey; "Industrial Electrical Heating from the Central Station Standpoint," by Mr. A. Strauch; "The Theory and Application of Electrical Industrial Heating," by Mr. E. Kramer. Attendance 52.

Schenectady.—December 16, 1921, Edison Club Hall. Subject: "A Practical Method of Assisting Prosperity in America." Speaker: Mr. O. K. Davis, Secretary of the National Foreign Trade Council. Attendance 100.

Seattle.—December 10, 1921. The meeting took the form of an inspection trip of the U. S. S. *Tennessee* (electrically driven), at the Puget Sound Navy Yard. This was followed by a dinner at the Navy Yard Hotel, after which the following speakers were introduced: Commander A. M. Charlton, Engineer Officer of the U. S. S. *Tennessee*, who spoke on the subject of "Main Drive of the Tennessee"; Lieutenant Commander Hugh L. White, Electrical Officer, on "The Service Power Plant"; Commander Russell S. Crenshaw, Gunnery Officer, on "The Battery of the Tennessee." Attendance 90.

Syracuse.—December 16, 1921. Subject: "The Vacuum Tube," illustrated by lantern slides. Speaker: Dr. Saul Dushman, of the General Electric Company. Attendance 53.

Toronto.—December 9, 1921, Mining Building, Toronto University. Subject: "Distribution Records and Overhead Distribution." Speaker: Mr. C. E. Schwenger, of the Toronto Hydroelectric System. Attendance 75.

Urbana.—December 15, 1921. Motion pictures of invisible actions, etc., shown by Dr. Rowland Rogers, of the Picture Service Corporation. Attendance 275.

Washington.—December 13, 1921, Cosmos Club. Subject: "Types of Okonite Wire," read by Mr. White, owing to the illness of the author, Mr. Hackett. The subject was illustrated by five reels of moving pictures. Mr. J. P. Millwood spoke on the subject of "Specifications for Insulated Wire." Messrs. Dalgleish, Helms and Beals, all of the C. &. P. Telephone Company, were called on to take part in the discussion. Refreshments were served. Attendance 208.

January 10, 1922, Department of Interior Building Auditorium. Joint meeting of Washington Sections A. I. E. E. and A. S. M. E. Subject: "Superpower Survey." Speakers: Mr. Henry Flood, Jr., who spoke on the Steam Generating Stations of the Superpower Survey; and Mr. L. E. Imlay on the hydroelectric developments of the system, the general types of transmission lines involved, the transmission voltages to be employed, the operation and regulation of the system, and the conclusions to be drawn. Both papers were discussed by Mr. N. W. Storer, of the Westinghouse Elec. & Mfg. Company. Preceding the meeting, dinner was served at the Cosmos Club. Attendance at meeting, 350.

Worcester.—December 15, 1921, E. E. Dept. of W. P. I. Subject: "Electric Meters." Speaker: Mr. A. R. Rutter, of the Westinghouse Electric & Mfg. Company. Attendance 51.

BRANCH MEETINGS

Alabama Polytechnic Institute.—December 15, 1921. Subject: "Alternating Current as Applied to Railway Electrification." Speaker: Mr. O. D. Williams, Class of '22. Attendance 25.

University of Alabama.—November 8, 1921. Subject: "The Electrical Apparatus Used on Automobiles." Speaker: Mr. F. R. Maxwell, Jr. Attendance 14.

November 22, 1921. Subject: "A Trip Through the Westinghouse Works" (illustrated). Speaker: Mr. R. F. Wright, of the Birmingham Office of the Westinghouse Company. Attendance 41.

Brooklyn Polytechnic Institute.—December 16, 1921. Subjects: "Street Lighting in New York City, Past and Present," by Mr. Howard Dempsey; "The Possibilities and Uses of the Audion Tube," by Professor Morecroft, of Columbia University. Attendance 85.

Bucknell University.—January 9, 1922. Subject: "Resume of the Problems of the Electrical Engineers." Speaker: Professor Simpson. Attendance 33.

Carnegie Institute of Technology.—January 5, 1922. Subject: "Western Electric Company's Telephone Circuits."

Speaker: Mr. John C. Gates, Jr., Senior Electrical. Moving pictures of the application of electricity to rolling mills and railroads were shown. Attendance 56.

Georgia School of Technology.—December 12, 1921. Subject: "Surge Arrester." Speaker: Mr. C. E. Bennett, Chief Engineer of Electro Service Company. Attendance 75.

State University of Iowa.—December 21, 1921. Subjects: "The Liberty (Ford Motor Co.) Generator," and "Transmission Line Condensers," by Messrs. McCall and McLuen respectively. A movie entitled "Starting and Lighting Systems on Automobiles," was also shown. Attendance 31.

University of Kentucky.—November 28, 1921. Subject: "The Importance of Initiative." Speaker: Professor C. H. Anderson. Attendance 35.

Lehigh University.—December 8, 1921. Subjects: "Experiences in Traction Maintenance," by Mr. J. W. Horine, '22; "Influence of Power Factor on Rate Determination," by Mr. W. W. Perry, of the Pennsylvania Utilities Company, Easton, Pa. Attendance 72.

School of Engineering of Milwaukee.—December 2, 1921. Subject: "Electric Control in the Iron and Steel Industry." Speaker: Mr. N. L. Mortensen, of the Cutler-Hammer Mfg. Co., Milwaukee, Wis. Attendance 66.

University of Nebraska.—December 14, 1921. Inspection trip to the plant of the Lincoln Telephone and Telegraph Company. Refreshments were served by the Telephone Company. Attendance 48.

University of North Dakota.—December 6, 1921. Reorganization meeting. Election of officers as follows: Chairman, E. L. Hough; Secretary-Treasurer, S. W. Winje. Attendance 23.

Joint meeting with University Engineering Society. Subjects: "The Rocky Point Radio Station," by Mr. A. M. Langford; "1,000,000-Volt Experiments of the General Electric Company," by Mr. R. B. Witmer; "The Problem of Reorganizing the Government's Engineering Work," by Mr. S. W. Winje. Attendance 36.

Ohio Northern University—December 15, 1921. Smoker. Short Talks by Professor Small, Beckwith, Alden and Carpenter. Refreshments were served. Attendance 52.

January 5, 1922. Discussion on the laboratory equipment outlay and plans for future development. Attendance 37.

Ohio State University.—December 14, 1921. Subject: "The Future Role of the Economist and Engineer in Public Utility Fields." Speaker: Professor Clyde Ruggles. Attendance 20.

January 10, 1922. Subject: "The Vacuum Tube and Some of Its Applications." Speaker: Mr. John Mills, of the Western Electric Company. Attendance 100.

Oklahoma A. & M. College.—December 12, 1921. Subjects: "Failings of the Engineering Graduate," by Mr. B. B. Talley; "Checking Efficiency of Generating Plants," by Mr. O. Baker; "Electrifying Facilities for Port Operation," by Mr. Cecil Wells. Attendance 15.

University of Oklahoma.—December 21, 1921. Demonstrated lecture on the "Automatic Telephone," by Professor O. W. Walters; illustrated talk on the "Simple Magneto Telephone," by Mr. J. Swase; concert and lecture "The Radio Amateur." Attendance 42.

University of Pittsburgh.—January 4, 1922. Election of officers as follows: Chairman, C. A. Anderson; Vice-Chairman, W. J. Zuck; Secretary, A. F. Robert. Attendance 35.

Purdue University.—December 15, 1921. Subject: "The Commercial Side of Public Utility Engineering." Speaker: Mr. B. H. Gardner, of the Northern Indiana Gas & Electric Company. Attendance 61.

January 10, 1922. Subject: "Humanizing Engineering." Speaker: Mr. J. W. DeCou, of the Fairfield Manufacturing Company, Lafayette, Ind. Attendance 82.

Rensselaer Polytechnic Institute.—December 13, 1921. Subject: "The Application of Electricity in the Steel Industry." Speaker: Professor C. P. Eldred. Attendance 90.

Rose Polytechnic Institute.—December 12, 1921. Subject: "Automatic Illumination." Speaker: Professor Knipmeyer. Attendance 232.

December 20, 1921. Motion pictures illustrating the automobile ignition system were shown. Attendance 27.

Rutgers College.—December 9, 1921. Organization meeting. Election of officers as follows: Chairman, H. Goldsmith; Vice-Chairman, P. H. Betts; Secretary-Treasurer, T. P. Brown; Recording Secretary, C. H. Baker. Attendance 15.

December 15, 1921. Subject: "Essential Qualifications for Engineering Success." Speaker: Mr. C. R. Dooley, Manager of Personnel and Training, of the Standard Oil Company of New Jersey. Attendance 69.

January 11, 1922. The General Electric Company's 3-reel motion picture "King of the Rails" was exhibited. Attendance 74.

Swarthmore College.—November 4, 1921. Subject: "The Superpower System." Speaker: Mr. Arthur Stiles. Attendance 14.

December 16, 1921. Subject: "Automobile Ignition." Speaker: Mr. J. C. Fretz. Attendance 15.

Virginia Military Institute.—November 10, 1921. Lecture by Mr. J. M. S. Waring, of L. L. Summers & Company, Chicago.

December 2, 1921. Joint meeting of all engineering societies. Subject: "Bridges, Ancient and Modern." Speaker: Professor Charles M. Spofford, of Massachusetts Institute of Technology. Attendance 234.

December 17, 1921. Subjects: "History and Development of the Steam Engine," by Mr. W. V. O'Brien; "The Induction Motor," by Mr. H. M. Cannally. Attendance 34.

West Virginia University.—December 19, 1921. Subjects: "The New Three-Electrode Vacuum Tube," by R. D. Brown; "Storage Batteries," by C. R. Lowe; "Frequencies," by R. H. Mendelsohn; "Light Meters," by C. M. Hill; "The Licensing of Engineers in West Virginia," by G. A. Moffett; "Lighting Metal-Working Plants to Increase Production," by J. R. Richards. Attendance 19.

January 9, 1922. Subjects: "An Improved Bearing Alloy," by Gifford Nease; "Drying Out High-Voltage Transformers," by A. T. Richards; "Vacuum Lamps Compared with Gas-Filled Lamps," by L. T. Faulkner; "Insulation for Steel Mill Motors," by I. O. Myers; "Industrial Heating by Electricity," by C. Snyder. Attendance 23.

University of Wisconsin.—November 30, 1921. Annual initiation. After being shown how it is possible to stand 2330 volts without the quiver of a muscle or the twinkle of an eye, the initiatees proceeded to test the Kinetic Energy Equation. This was followed by a study in "he that will not work, shall not eat."

December 7, 1921. Discussion of the Electrical Show to be held in the near future. Attendance 46.

Employment Service Bulletin

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

MEN AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after a period of three months, during which period names and records will remain in the active files.

NOTE.—Notices for the JOURNAL **should be addressed to EMPLOYMENT SERVICE, 33 West 39th Street, New York, N. Y.,** *the employment clearing house of the Societies constituting the Federated American Engineering Societies, and* **not** *to the A. I. E. E.*

Notices for the JOURNAL are not acknowledged by personal letter, but if received prior to the 16th of the month will appear in the issue of the following month.

All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case **and forwarded to EMPLOYMENT SERVICE, as above.**

Replies received by the bureau after the position to which they refer has been filled will not be forwarded, and will be held by the bureau for one month only.

Information regarding the notices published is on file in the offices of the member societies of the Federated American Engineering Societies.

POSITIONS OPEN

TRANSMISSION LINE SUPERINTENDENT. Applicant must be conversant with practise in transmission lines 100.000-volt, three-phase, 50-cycle. He must be capable of taking entire charge of transmission system of approximately 400 miles of lines, must be familiar with both construction and operating work, and must be capable of handling native help. Reply stating age, experience, training and salary desired. Location India. X-1292.

ELECTRICAL AND MECHANICAL Constructing Engineering Company, with established reputation for reliability acquired through many years of successful business experience, desires man to help in estimating and following up progress of jobs. Preference will be given to technical graduate who has had successful experience in electrical contracting business. Must be able to give good reference from former employers. Position should be permanent and lead to rapid advancement for man who can make good. Location, New Jersey. V-30.

RESEARCH ASSISTANTS with physics and electrical engineering education. Recent graduates. Two or three men. Location East Pittsburgh. Application by letter. V-33.

ELECTRICAL ENGINEER for remote control and substation design. Must be thoroughly familiar with use of relays. Must be electrical engineering graduate, under 45 years of age. Full details of education, experience, salary and time available should be given in first letter. Location Pa. V-43.

DRAFTSMAN for checking electrical drawings, wiring diagrams, etc. Must be electrical engineering graduate, under 45 years of age. Full details of education, experience, salary and time available should be given in first letter. Location, Pa. V-44.

ELECTRICAL ENGINEER, technical graduate, desired by large light and power utility in Southwest for design and estimate work in Engineering Department on steam electric generating station, motor-generator substation, 12-kv. and 60-kv. transmission line and transformer substation and underground 4000-volt distribution system installations. Position is permanent and opportunities for advancement are excellent. Salary to start depends upon education and previous experience. In answering, applicants must give in first letter, full details of education, experience and employers' references, or applications will not be considered. V-45.

YOUNG ELECTRICAL ENGINEERS, (one or two) with technical training and both sales and factory experience. Must be able to make design layouts showing application of bearings to electric motors. Much prefer an unmarried man as work will require considerable traveling. Location, Ohio. V-47

ELECTRICAL INSPECTORS desired by large central stations near New York City. Must be experienced in design and construction of a-c. overhead distribution systems and capable of preparing plans for extensions of commercial and street lighting circuits. Give complete information including present salary and salary desired. X-1531.

SALES ENGINEER to sell handy trucks, a device for removing ash barrels. Territory northern N. J. (Morristown, Montclair, Paterson, Passaic, etc.) Commission basis. V-82.

ASSISTANT TO CHIEF ENGINEER OF large electric light and power company located in the middle west. Must be technical graduate with at least five years experience in engineering or distribution department of modern utility. Must have good sound business judgment, some knowledge of construction accounting, estimating and constructing overhead and underground distribution, etc. Excellent opportunity for young man with ambition. V-72.

ENGINEER on publicity and relating matters wanted by manufacturer of electrical apparatus. Graduate electrical engineer with experience in manufacturing engineering or selling rather than strictly publicity work. An opportunity for an electrical engineer who has found his work uncongenial, to try himself in the publicity field. V-135.

ELECTRICAL ENGINEER with technical education capable of taking complete charge of electrical equipment in plant having installed approximately 10,000 horse power d-c. and a-c. motors and generator service. Should have had practical experience in operation of large industrial plant using modern electric equipment. State salary expected. V-136.

MEN AVAILABLE

ELECTRICAL ENGINEER desires position in electrical engineering; design, or construction work; or general plant engineering. Reasonable offer considered, but wages commensurate with responsibility. E-3153.

ELECTRICAL ENGINEER expert on high-voltage and distribution problems, with wide experience in the design of high-voltage apparatus available for service in this country or abroad. Competent to take responsible charge of important work. Age 29. Member A. I. E. E. E-3154.

ELECTRICAL ENGINEER technical education, Assoc. A. I. E. E. Former Engineering Officer U. S. Navy. Wide experience with manufacture, installation and maintenance of d-c. equipment and storage batteries, also experience with automotive electrical work, railway car lighting and factory maintenance with a-c equipment. Age 33. Married. Located in Kansas. E-3155.

ELECTRICAL ENGINEER technical graduate in electrical engineering 1917. Employed General Electric Company engineering departments to date. Schenectady tests, and intensive training. Past supervisor turbine and electrical construction. Mechanical experience. Position desired capitalizing training. Available at once. E-3156.

A HIGHLY SUCCESSFUL DESIGNER of telephone transmission apparatus desires a position with a company that is interested in developing refined equipment for wireless broadcasting and receiving. Has had a broad experience in the transmission of music, in phonograph recording and reproducing electrically and with wireless amplifying circuits. E-3157.

EXECUTIVE graduate electrical engineer with three years business and office experience, one year sales, seven years engineering and executive experience available immediately. Employed at present. Formerly an executive engineer in Bell telephone system. Desires change early in 1922. Qualifications, references, etc., considerably above average. Prefer Cleveland or other Ohio location. E-3158.

INDUSTRIAL HEATING ENGINEER Assoc. A. I. E. E. Age 29, technical graduate, 1914. Desires position with central station company or manufacturer in sales engineering work on electric heating in industrial processes. Thoroughly familiar with heating field in all temperature ranges and experienced in electrical sales, purchasin.g construction, operating and preferred stock work, E-3159.

MECHANICAL AND POWER ENGINEER technical graduate, B. S. and M. E., age 30, eight years broad experience, machine shop, metallurgy, sugar engineering, industrial and power plant practise, operation, design, layout, calculations, heating, distribution of steam, water, etc., investigation, reports. Executive and business ability. E-3160.

ENGINEER with 25 years experience in designing, constructing and managing hydroelectric and allied properties is available for employment in foreign countries. E-3161.

ELECTRICAL ENGINEER. Age 30, married, I. C. S. graduate, Assoc. A. I. E. E., desires a responsible position with power company in North Central or Western States. Two years experience on construction and maintenance work, three years central station operation, three years hydroelectric station operation and maintenance. Best of references. One month notice. Salary, $3000. E-3162.

ERECTING ENGINEER. Desires position as assistant manager, or superintendent, in public

utilities, or industrial plant. Has had seven years apprenticeship electrical engineering with technical training. Seven years as erecting engineer, with foreign experience, and previous shop work with large manufacturing company. Age 30, married. Assoc. A. I. E. E. E-3163.

TRY this Advertiser for RESULTS; now employed, desires change (Southern District preferred). Ten years broad general, active experience with steam railroad electric practise, not including seven years apprenticeship, fully equipped to take charge, shops, construction, power system and industrial plant equipments, also experienced in marine electric installations. Have learned how to make best use of material and men available under difficult conditions and keep things running. Have the acquisition of self-control and self-discipline, will consider other position than railroad. E-3164.

ELECTRICAL ENGINEER age 34, Member A. I. E. E. with initiative ability, fourteen years of varied electrical experience with large paper mills in the United States, Canada and Newfoundland. Just completed installation of electrical equipment in large pulp and paper mill. Services available immediately. E-3165.

BUSINESS OPPORTUNITIES IN INDIA. A chief electrical engineer who is an Associate of A. I. E. E. desires to form connections with American manufacturers to introduce their goods in India. Has good connections, references and canvassing abilities. Automobile, electric goods, and other small job machines are particularly required. Terms by correspondence. E-3166.

FACTORY EXECUTIVE and INDUSTRIAL ENGINEER, age 41, with practical and technical training, broad experience in production work, in investigation, planning, routing, cost work, etc., wishes suitable position with manufacturing concern. E-3167.

GRADUATE ELECTRICAL ENGINEER, age 32, desires position with railway or light and power company on operation or construction. Five years experience in various positions with an electric elevator company and six years experience in operation and construction of power plant and substation machinery and overhead and underground lines. At present with interurban railway company with high-tension power lines. E-3168.

TECHNICAL GRADUATE. Eight years experience in electric transmission and distribution desires position as assistant to managing executive or as power and commercial engineer with public utility company, preferably located in the East. E-3169.

ELECTRICAL ENGINEER technical graduate, open for position. Fifteen years experience in electrical railway and power plant work. Can take charge of operation or construction work. Familiar with all the operating, maintenance and construction work in the above fields, including high-tension lines. Experienced in laying out work and estimating costs. E-3170.

ELECTRICAL ENGINEER. Associate A. I. E. E. Age 31 with 12 years experience in engineering and construction, covering the responsibility of supervising estimating, and laying out work. Desires position affording opportunity in this field. E-3171.

INDUSTRIAL ELECTRICAL ENGINEER, age 38, with 15 years experience in the design installation and maintenance of electrical equipment in large industrial and mining works. Broad experience in industrial power distribution, motor application and industrial transportation including electric cranes, trucks and locomotives. Desires position in above lines, or would consider taking interest in electrical repair business. E-3172.

SUPERINTENDENT, 12 years experience, line, industrial, and power plant construction and maintenance, transmission distribution and central station engineering. Low and high-tension work up to 50,000 volts, can handle men, know office systems and costs. At present electrical engineer for large pulp and paper company. Married, age 30. Available 30 days notice. E-3173.

ELECTRICAL ENGINEER M. I. T. 1915. Experience: 4 years central station maintenance and operation in city of 100,000; one year large central station, design and purchase of materials; one year rate work for company owning 12 gas and electric properties. At present electric distribution engineer in rapidly growing territory. Desires permanent position with advancement assured. Available on reasonable notice, salary, $4500. E-3174.

EXECUTIVE ELECTRICAL and MECHANICAL ENGINEER, 18 years broad experience in development, manufacture and sale of switchboards, panelboards and control devices. Salary $3500. Available on short notice. E-3175.

GOING ABROAD—ELECTRICAL ENGINEER with 12 years sales and executive experience expects to go to Europe in June for indefinite stay probably 2 or 3 years. May later go to India, Australia and the Far East. Speaks French, learning Italian. Wishes to represent 2 or 3 electrical companies to establish European agencies or branches or to act as direct representative or make special investigations. E-3176.

ENGINEER, single, age 27, technical training, 11 years electrical experience with construction companies, chiefly substations and power houses of high and low-tension voltages, supervising and under supervision, willing to render any kind of services at any place required; familiar with safety control wiring. Assoc. A. I. E. E. E-3177.

ELECTRICAL-MECHANICAL INDUSTRIAL and DESIGNING ENGINEER age 42; university graduate; able executive. Fifteen years' shop, office and field experience, in estimating, appraisal, engineering economics, design construction and equipment of power plants, substations, and factories. Salary in proportion to responsibilities. E-3178.

TECHNICAL GRADUATE with seven years experience as a radio electrician and laboratorian at Navy Yard, Boston, and two years of general laboratory work in the Standardizing Laboratory of the General Electric Company at Lynn, Mass., desires a change of position. Will go any where in world if the inducements are high enough. E-3179.

ELECTRICAL INSTRUMENT MAKER Associate A. I. E. E. Age 36. Six years rebuilding and calibrating electrical and mechanical instrument. Have handled foreign and all makes of American instruments. Am particularly interested in radio instruments including thermocouples; hot-wire current-squared. Thermo galvanometers and ammeters. Hopkins tachometers and Hoskins pyrometers. Available short notice. E-3180.

TECHNICAL GRADUATE age 31, ten years experience including drafting, testing inspection, telephone switchboard installation and engineering. General knowledge of cost accounting. Present salary $2000. Desires position with small electrical manufacturing concern in vicinity of New York City. E-3181.

ELECTRICAL ENGINEER technical graduate; age 32, single, Associate A. I. E. E. Executive experience, seven years in electric utility field, including operation of high-tension transmission systems. Desires position with electric utility. E-3182.

SALES ENGINEER EXECUTIVE desires to represent in New York one or several high grade non-interfering manufacturing accounts covering electrical and mechanical equipment and appliances. Have wide acquaintance among buyers in this territory. E-3183.

EXECUTIVE ENGINEER electrical graduate, 15 years broad experience with large power and construction companies in office and field supervision, design, construction, operation and maintenance of power plants, substations, electric railways, transmission lines and distributing systems. Knowledge of Spanish. At present in charge of an appraisal which will soon be completed. E-3184.

GRADUATE ELECTRICAL ENGINEER Massachusetts Institute Technology, five years supervision engineering practise, two years executive work overseas, present manager small electrical manufacturing company, desires change for broader field of activity; manufacturing or industrial development; initiative, perseverance, coupled with training and character, developing a person YOU can depend upon; age 32, married; present salary rate $3,000; available on reasonable notice. E-3185.

ELECTRICAL ENGINEER, age 36, married, desires position as manager or superintendent of construction and operation with a public utility company or manufacturing company. Has 15 years experience in the design and construction of power plants. Capable of promoting research work. Salary $3600 yearly. Available at once. E-3186.

RECENT GRADUATE ELECTRICAL ENGINEER. University of Michigan. Age 27. Two years practical experience with steam railroad. Position wanted with some well established electrical concern. Location U. S. Available immediately. E-3187.

YOUNG MAN. Age 26, single, desires position with advancement. E. E. training. At present, and for 6 years employed by public utility, also 3 years experience in auditing department of Steamship Company, A-1 references. Would prefer position as assistant to executive. Will consider other opportunities. Available at once. E-3188.

GENERAL MANAGER. Over twenty years experience in construction, operation, management Public Utilities. General manager large Railway, Gas and Power company prior to war. Know business from the coal pile to the public. Successful executive, energetic and tactful. Age 47, married, American, several years experience abroad, speaks Spanish. Available now. E-3189.

ELECTRICAL ENGINEER. Technical graduate, married. General Electric Test. Cottrell electrical precipitation work, steel and concrete construction. Experience in chemical plants, oil refineries and lamp-black manufacture. Desires position as plant engineer. Can handle men. E-3190.

MECHANICAL AND ELECTRICAL ENGINEER desires position where a thorough knowledge of boilers, engines, pumps, dynamos, elevators, gas engines, turbines, and condensers is required. Location anywhere salary $6000. 20 years experience. E-3191.

GRADUATE ELECTRICAL ENGINEER desires position as sales or application engineer or with consulting engineer. Age 28, married. Two years sale of electrical supplies, power apparatus and pole line material, and layout of plants. Westinghouse Technical courses. Now employed. Best of references and records. E-3192.

ELECTRICAL DESIGNER long experience in high and low-tension underground conduit and cable systems. Designs, specifications and estimates. E-3193.

MECHANICAL ENGINEER. General engineering experience, civil, electrical, mechanical. Ex. Lt. U. S. Engineers. Pile driving, caisson foundation, excavations, surveying, earthwork, railroad construction, power house installations, boilers, pumps, engines, generator, switchboards. Good excutive, American college graduate. Age 26. Single. E-3194.

ELECTRICAL ENGINEER, Graduate Mass. Inst. Technology. Member A. I. E. E. Experience chief draftsman, 3 years construction and installation electric plants, high-tension lines and apparatus, 1 year foreign experience steam electric power-plant and inspection. Good knowledge of French and Spanish. Initiative and executive ability. Available on short notice. Age 36. Excellent references. E-3195.

YOUNG ELECTRICAL ENGINEER is desirous of making a connection with a radio concern selling, installing or lecturing. At present employed as an engineer for a large manufacturing concern during the day and as an instructor in wireless construction and operation evenings. Would be willing to invest a small amount in the case of business offer. E-3196.

ELECTRICAL ENGINEER, B. S. degree. Class of 1921. Student member A. I. E. E. and A. A. E. Nine months experience installing and maintaining work in central station power plant. Commercial course, also German and Spanish in high school. Age 22, single. Location immaterial Foreign service considered. E-3197.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED JANUARY 13, 1922

ALLEN, HARRY, Assistant Chief Electrician, Dodge Brothers, Detroit, Mich.

APPLEGATE, LINDSAY MORTIZ, 801 Hancock St., Portland Ore.

ARDIFF, ROBERT JAMES, Engineering Dept., Indiana Bell Telephone Company, Indianapolis, Ind.

BAKER, CHARLES LEROY, Chief Electrician, Fairmont Creamery Company, Green Bay, Wis.

BALL, CLARENCE EUGENE, Transmission Engineer, The Home Tel. & Tel. Co., Spokane, Wash.

BASSETT, CLARK LODGE, Electrical Engineer, The Detroit Edison Company, 2000 2nd Ave., Detroit, Mich.

BEALEY, WALTER DeV. Fieldman, The Pacific Tel. & Tel. Company, 410 Artisans Bldg., Portland, Ore.

BELLAMY, JOHN I. S., Telephone Engineer, Automatic Electric Company, 947 W. Van Buren St., Chicago, Ill.

BLACKWELL, WILLIAM THOMAS, Illuminating Engineer, Westinghouse Lamp Co., 165 Broadway, New York, N. Y.

BLISS, WILLIAM JAMES, Assistant to Superintendent of Distribution, Ohio Power Co., Steubenville, Ohio.

BROWN, JOHN J., Electrical Engineer, Westinghouse Electric & Mfg. Co.; res., 5331 Angora Terrace, Philadelphia, Pa.

BRUNO, WILLIAM ATTILIO, Electrical Engineer, KleniSchmidt Electric Company, 36 Flatbush Ave. Extension, Brooklyn; res., 300 W. 17th St., New York, N. Y.

BURGESS, BERT I., Testing Electrical Machinery, Canadian General Electric Co., Ltd.; res., 333 Reid St., Peterboro, Ont., Canada.

BUTLER, WILLIAM CAMP, Chief Engineer, Chilian Electric Tramway & Light Co., Ltd., Casilla 1557, Santiago, Chile, S. A.

CANNING, DOW VERNON, Testing Dept., Canadian General Electric Co.; res., 513 Gilmour St., Peterboro, Ont., Canada.

CANTRELL, WILLIS R., 1120 Prospect Ave., Plainfield, N. J.

CARD, READ H., Equipment Attendant, American Tel. & Tel. Co., 1422 Hurt Bldg., Atlanta, Ga.; Denmark, S. C.

CARMEAN, JAMES HENRY, Operating Dept., Kansas City Power & Light Company; res., 1613 E. 9th, Kansas City Mo.

CASEY, HARRY JOSEPH, Distribution Engineer, United Railways & Electric Company, Baltimore, Md.

CHEWNING, VORIS ORVILLE, Superintendent of Substations, Illinois Traction System; res., 427 S. 7th St., Springfield, Ill.

COLEMAN, GEORGE BYRON, Electrical Engineer & Inventor, Majik Electric Appliance Co.; res., 698 Bush St., San Francisco, Cal.

CONNELY, C. B., Engineer, Power & Mining Engineering Dept., General Electric Company, Schenectady; res., 5 Sunnyside Road, Scotia, N. Y.

COOK, GEORGE CHURCHILL, Vice-President & Manager, Tidewater Crossarm & Conduit Co., 1885 Canal St., Tacoma, Wash.

CRESSMAN, EDWARD WALTER, Electrical Draftsman, Puget Sound Power & Light Company, 605 Electric Bldg., Seattle, Wash.

CRISPELL, KENNETH GUY, Assistant in Engineering Dept., American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

DAHL, OTTO GUSTAV C., Research Assistant, Electrical Engineering Dept., Mass. Institute of Technology; res., 371 Harvard St., Cambridge, Mass.

DAVIDSON, OTTO CONRAD, JR., North Carpenter Avenue, Iron Mountain, Mich.

DE LAND, DONALD WILLARD, Electrical Division, Board of Education, Municipal Bldg., New York; res., 141 25th St., Elmhurst, N. Y.

DEVENDORF, NORMAN LE ROY, Member of Instruction Dept., Consumers Power Co.; res., 1106 Fourth St., Jackson, Mich.

d'HARCOURT, J., Engineer, French Thomson-Houston Co.; International General Electric Company, Schenectady, N. Y.

DMYTROW, NESTOR, JR., Manager, New York Office, Bailey Meter Company, 50 Church St., New York, N. Y.; res., 507 Elm St., Cranford, N. J.

DODSON, RALPH E., Consulting Engineer, Louis A. Roberg & Company, 802 St. Paul Bldg., Cincinnati, Ohio; res., 47 Linden St., Ludlow, Ky.

EDWARDS HAROLD SEWELL, Meter Man, Kentucky Utilities Company, Harlan, Ky.

ENRIQUEZ, ALFONSO, Electrical Engineer & Contractor; 657 Dart St., Paco, Manila, P. I.

ESTEVE, CARLOS ALBERTO, The Woodard Machine Co., Wooster, Ohio.

FELDMAN, JACOB G., Allied Electric Co., Inc., Grand Central Terminal, New York, N. Y.

FERGUSON, FRANK L., President, The Hessel & Hoppen Co., 36 Crown St., New Haven, Conn.

FIRKET, GUILLAUME C., Graduate Student, Cornell University; res., 110 Highland Place, Ithaca, N. Y.

FLYNN, JOHN P., Draftsman, Toronto Hydro-Electric System, 226 Yonge St.; res., 158 First Ave., Toronto, Ont., Canada.

FOSTER, EDGAR WOLCOTT, Electrical Tester, Brooklyn Rapid Transit Co., 500 Kent Ave., Brooklyn, N. Y.; res., 161 Ridge Road, Rutherford N. J.

FOSTER, JAMES CLARK, Designing Draftsman & Electrical Engineer, 422 49th St., Brooklyn, N. Y.

GIBBONS, EDWARD JAMES, Sales Dept. General Electric Company, Oliver Bldg., Pittsburgh, Pa.

GLATZEL, EARLE DEWEY, Electrical Engineering Dept., (Radio), Detroit Edison Company; res., 614 W. Philadelphia, Detroit, Mich.

GRIER, LOUIS NORMAN, Electrical Engineer, The United States Aluminum Company; res., 1311 Orchard Ave., New Kensington, Pa.

GROFF, WILLIAM ELLSWORTH, President, W. E. Groff Company, Inc., 306 Easton National Bank Bldg., Easton, Pa.

HAGY, BURTIS EDWIN, Design Calculator, Philadelphia Electric Company; res., 3906 Spruce St., Philadelphia, Pa.

HAIG, JOHN McDONALD, Assistant Superintendent, Transformer Dept., Ferranti Transformer Co.; res., 18 Roblock Ave., Toronto, Ont., Canada.

HAINES, ARTHUR J. D., Electrical Engineer 951 Hamilton St., Allentown, Pa.

HALL, ERNEST, Workshop Foreman, South African General Electric Co., Ltd., Capetown, South Africa.

HEARN, GEORGE K., Inspector, Westinghouse E. & M. Co.; United Electric Light & Power Company, 134th St., New York; res., 105 Herkimer St., Brooklyn, N. Y.

HERR, ROBERT FRANTZ, Research Dept., Philadelphia Storage Battery Company, Ontario & "C" Sts., Philadelphia, Pa.

HIGGS, WALTER FRANK, Founder & Senior Partner, Higgs Bros., Sand Pits, Birmingham, England.

HOCKETT, WILLIAM JOSEPH, Director, Industrial Service, General Electric Company; res., 2536 Maple Place, Ft. Wayne, Ind.

HOLTERS, JOSEPH W., Sales Dept., Allis-Chalmers Mfg. Company, Norwood, Ohio; res., 1810 Greenup St., Covington, Ky.

HORINE, ERNEST ENGLAND, Electrical Engineer, National Carbon Company, Inc., Cleveland, Ohio.

HURD, HAROLD R., Equipment Man, Dept. of Electrical Engineering, University of Minnesota, Minneapolis, Minn.

ISAWA, TATSUO, International General Electric Company, Schenectady, N. Y.

JEFFREY, ARTHUR E., Electrician, Lord Electric Company, 9 Cudworth St., Medford, Mass.

JOHNSTON, JOHN FLYNN, Long Lines Plant Dept., American Tel. & Tel. Co., Selma, N. C.

JOHNSON, LOUIS B., Engineer on Foreign Wire Relations, Indiana Bell Telephone Company; res., 417 E. 50th St., Indianapolis, Ind.

KEENAN, EDWIN C., General Superintendent, Telegraph, N. Y. C. R. R., 486 Lexington Ave., New York, N. Y.

KELLY, JAMES H., Salesman, Western Electric Co., Inc., 762 Commerce St., Tacoma, Wash.

KEMNA, ROD HERMAN, Station Operator, Butte Electric Railway Company; res., 724 S. Main St., Butte, Mont.

KENNEDY, GORDON THOMAS, Telephone Engineer, Western Electric Company; res., 4053 Kenmore Ave., Chicago, Ill.

KERN, CHARLES L., Electrical Operator, Kansas City Power & Light Company; res., 2325 Montgall ave., Kansas City, Mo.

KING, HORACE WALDORF, Inspector, Underwriters' Laboratory, 25 City Hall Place, New York; res., 61 Cook Ave., Meriden, Conn.

KIRLIN, GEORGE, Manager, Eastern District, Standard Underground Cable Company, of Canada, Ltd., 702 McGill Bldg., Montreal, P. Q.

KRETSCHMAR, GEORGE GUSTAV, Professor of Physics, Walla Walla College, College Place, Wash.

LANGE, HAROLD THEODORE, Assistant Engineer, Madison County Light & Power Company; res., 3605 McDonald Ave., St. Louis, Mo.

LANIGAN, LEO PAUL, Testing Dept., General Electric Company; res., 231 Seward Place, Schenectady, N. Y.

LAUTERBACH, FREDERICK JOHN, 8934 86th St., Woodhaven, N. Y.

LEE, FREDERICK W., Instructor in Electrical Engineering, Johns Hopkins University, Baltimore; res., Owings Mills, Md.

LEWIS, ARCHIE L., Operator, North Pacific Public Service Company, Power House, Fort Highland Ave., Bremerton, Wash.

LINCOLN, ALDEN A., Special Assistant, The Connecticut Company, 129 Church St., New Haven, Conn.

LINDSAY, RUSSELL HESS, Instructor in Electrical Engineering, University of Colorado; res., Acacia House, 1129 13th St., Boulder, Colo.

LOGAN, MAXWELL BELLEW, Draughtsman, Hydroelectric Power Commission of Ontario, 190 University Ave., Toronto, Ont., Canada.

LOOSE, WILLIAM HENRY, Technical Clerk, Toronto Hydro-Electric System, 226 Yonge St., Toronto; res., Weston, Ont., Canada.

LYON, GORDON MAXWELL, Tester, Canadian General Electric Co. 185 King St., Peterboro, Ont., Canada.

MACAULEY, JAMES EDWARD, General Foreman, Underground Dept., Hartford Electric Light Co. 266 Pearl St., Hartford, Conn.

MANSELL, WALTER HENRY, Chief Electrician, W. F. Schrafft & Sons Corporation, 160 Washington St. N., Boston; res., 5 Park St., Medford, Mass.

MAZZARELLA, FRANK, Inspector, Brooklyn Edison Co., 569 Fulton St., res., 20 Highlawn Ave., Brooklyn, N. Y.

McALPINE, DUNCAN C., Construction Foreman, Anaconda Copper Mining Co., Butte, Mont.

McFARLAND, THOMAS CLAIR, Instructor in Electrical Engineering, University of California; res., 1508 Arch St., Berkeley, Cal.

McHUGH, JOHN ANTHONY, Assistant Engineer, The New York Edison Company, Irving Place & 15th St., New York, N. Y.

McKAY, RICHARD, Engineering Dept., Washington Water Power Company; res., 1017 W. Maxwell, Spokane, Wash.

McKENDRICK, RAY HUSTED, Electrician, Motor Repair Dept., New Haven Electric Company, New Haven; res., 46 Center St., West Haven, Conn.

MERTZ, RALPH H., Electrical Engineering Dept., Detroit Edison Company; res., 9353 Stoepel Ave., Detroit Mich.

MINER, ELLSWORTH FROST, General Superintendent & Director, Litchfield Electric Light & Power Co., Litchfield, Conn.

MORRIS, GLEN S., Engineering Dept., Kansas City Power & Light Company; res., 3014 E. 37th St., Kansas City, Mo.

MOULTON, THOMAS T., Electrical Engineer, Pacific Fruit Express Company, 65 Market St., San Francisco, Cal.

MUNRO, DAVID L., Draftsman, Hydro-Electric Power Commission of Ontario, 190 University Ave., Toronto, Ont., Canada.

NICHOLS, REED J., Radio Telephone & Telegraph Operator, Ford Motor Company, Northville; res., 2981 Manistique Ave., Detroit, Mich.

O'CONNOR, JOHNSON, Assistant Engineer, Meter & Instrument Dept., General Electric Co., Lynn, Mass.

OLDREY, KENNETH FRANCIS, Student, Y. M. C. A.; res., 3123 Liberty Street, Erie, Pa.

OSGYANI, GASTON LOUIS, Equipment Attendant, American Tel. & Tel. Company; 423 W. 21st. St., New York, N. Y.

PARVIN, EDWARD GARFIELD, Electrical Engineer, Zobell Electric Motor Corporation, Garwood; res., 402 E. 2nd Ave., Roselle, N. J.

PEARCE, THOMAS CARROLL, Chief Operator, Potomac Electric Power Co., Washington, D. C.

PENNEY, LESTER TUTHILL, Wire Chief's Supervisor, Nassau County, New York Telephone Co., 256 Franklin St., Hempstead, N. Y.

POLLOCK, ROBERT BODE, Engineering Department, Southern California Edison Company; res., 6629 Makee Ave., Los Angeles, Calif.

POPE, MARK COOPER JR., Sales Engineer, The Electric Storage Battery Company, 1823 L St., N. W., Washington, D. C.

ROBERTS EDWIN WALTER, Electrical Draftsman, U. G. I. Contracting Co., 1401 Arch St., Philadelphia, Pa.; res., Haddonfield, N. J.

ROCHE, GEORGE JOSEPH, Post Graduate Student in Electrical Engineering, Lehigh University; res., 438 Martel St., Bethlehem, Pa.

ROUDEBUSH, GEORGE H., JR., Telephone Engineer, The Ohio Bell Telephone Co., 4300 Euclid Ave., Cleveland, Ohio.

RULE, THOMAS WALTER, Engineering Dept., Southwestern Bell Telephone Company, 500 Central National Bank Bldg., Topeka, Kans.

RUTHERFORD, BURTON GLADSTONE, Testing Dept., Canadian General Electric Co.; res., 265 Reid St., Peterboro, Ont., Can.

SCHMELZ, FREDERICK CHARLES, Instructor, Cass Technical High School; res., 5699 Seminole Ave., Detroit, Mich.

SHERBINE, HARRY M., Chief Electrician, Hudson Motor Car Company; res., 518 Continental Ave., Detroit, Mich.

SILING, PHILIP FRANCIS, Telephone Engineer, Engineering Dept., American Tel. & Tel. Co., 195 Broadway New York, N. Y.

SIMONS, DONALD MacLAREN, Standard Underground Cable Company, 604 Westinghouse Bldg., E. Pittsburgh, Pa.

SINGER, EMANUEL, 504 West 171st St., New York, N. Y.

SLANE, AMBROSE F., Electrical Tester, Brooklyn Edison Company Inc.; res., 249 Lincoln Ave., Brooklyn, N. Y.

SLOAN, JOHN HAMILTON, Electrical Draftsman, Hydro-Electric Power Commission of Ontario; res., 81 Gates Ave., Toronto, Ont., Canada.

SMITH, ERIC D., Power Equipment Engineer, Automatic Electric Company; res., 500 Diversey Blvd., Chicago. Ill.

SMITH, HARRY H., Superintendent of Power & Distribution, The Northern Connecticut Light & Power Company, 15 Central St., Thompsonville, Conn.

SPEER, GEORGE ALEXANDER, Superintendent, Niagara Plant, Niagara Falls Power Company, Niagara Falls, N. Y.

SPICKARD, LENNEY OLEN, Chief Operator, Puget Sound Power & Light Company, 1902 Commerce St., Tacoma, Wash.

STELLE, CHRISTOPHER B., Assistant Superintendent, Indiana & Michigan Electric Company, 220 W. Colfax Ave., South Bend, Ind.

STEWART, HENRY GREENWOOD, Supt. of Power, Winnipeg Electric Railway Company, Winnipeg, Man.

STOPPS, LEONARD GEORGE, Draftsman, Canadian Westinghouse Company, Ltd.; res. 23 London Ave., Hamilton, Ont., Canada.

STOVER, WILLIAM BEAVER, Sales Dept., Westinghouse Electric & Mfg. Co., Plane & Orange Sts., Newark, N. J.

STREBIG, JOHN I., Chief of Electrical Bureau, City of York, 25 South Duke St., York, Pa.

TAYLOR, JOHN WATSON RAY, Sales Engineer, Canadian Westinghouse Co., Bank of Hamilton Bldg., Toronto, Ont., Canada.

TOMLIN, AMOS C., Meter Tester, Worcester Electric Light Company; res., 82 Paine St., Worcester, Mass.

TOMLINSON, FREDERICK JOHN, Testing Dept., Canadian General Electric Co.; res., 93 Aylmer St., Peterboro, Ont., Canada.

TORNER, J. V. H., Manager, Wapsie Power & Light Company, 101 E. 1st St., Mt. Vernon, Iowa.

TOWNE, CECIL D., Manager & Director, Milo Electric Light & Power Company, West Main St., Milo, Maine.

TUCKER, CARLTON EVERETT, Instructor in Electrical Engineering, Mass. Institute of Technology, Cambridge, 39, Mass.

TURNQUIST, FRANK ALBERT, Engineer, Westinghouse Lamp Company, Bloomfield; res., 320 Mt. Prospect Ave., Newark, N. J.

VALLARTA, MANUEL SANDOVAL, Graduate Student, Mass. Institute of Technology, Cambridge; res., 1277 Commonwealth Ave., Boston, Mass.

VAN HORN, RICHARD HENRY, Designing Engineer, Construction Engineering Dept., General Electric Co.; res., 231 Seward Place, Schenectady, N. Y.

VAN TASSEL, ABRAM, Electrical Contractor, 507 Fifth Ave., New York, N. Y.

VOGT, OTTO E., Operator of Electrical Machinery, Electrical Testing Laboratories, 80th St. & East End Ave., New York, N. Y.

VOLLMER, ROBERT M., Shift Load Dispatcher, Washington Street Station, Utica Gas & Electric Co.; res., 1022 Albany Street, Utica, N. Y.

WALKER, GLEN HART, Testing Department, General Electric Company; res., 4 Union St., Schenectady, N. Y.

WEINBACH, MENDEL P., Associate Professor of Electrical Engineering, University of Missouri; res., 303 Waugh Ave., Columbia, Mo.

WIEGNER, WILLIAM K., Draftsman, The Philadelphia Electric Company; res., 5420 Osage Ave., Philadelphia, Pa.

WILD ALBERT EDWARD, Draftsman, Toronto Hydro-Electric System 226 Yonge St.; res., 89 Waverly Road, Toronto, Ont., Canada

WILSON, GILBERT T., Electric Power & Light Dept., Timaru Borough Council, Timaru, N. Z.

WOODSON, WILLIAM C., Combustion Engineer, Union Electric Light & Power Co., St. Louis; res., 7214 Lindell Blvd., University City, Mo.

WOTIER, ARTHUR A., Electrical Engineer, Winchester Repeating Arms Company; res., 12 Helen St., Highwood, New Haven, Conn.

WRIGHT, PAUL COCANOUR, Engineer, Ohio Bell Telephone Company, 4300 Euclid Ave., Cleveland, Ohio.

YALE, CHARLES M., Superintendent of Distribution, The Hartford Electric Light Company, 266 Pearl St., Hartford, Conn.

YAMAMURA, TADAYUKI, Designing Engineer, Electrical Dept., Kawasaki Dockyard, Kobe, Japan.

YORTON, ALLISON TALMADGE, Distribution Engineering Dept., Detroit Edison Company, Edison Service Bldg., 2000 Second Ave., Detroit Mich.

Total 144.

ASSOCIATES REELECTED JANUARY 13, 1922

FREEMAN, RICHARD M., Meter Supervisor, Pacific Power & Light Company, Walla Walla, Wash.

PALMER, GUY H., Resident Engineer, Edward J. Cheney, New York; Adirondack Power & Light Corp., Schenectady, N. Y.

SQUIRE, WILLIAM JOHN, Consulting Engineer & Proprietor, Squire Electric Company, 401 Wyandotte St., Kansas City, Mo.

YUILL, ALEXANDER CLAUDE ROY, Consulting Engineer, 626 Pender St. West, Vancouver, B. C.

MEMBERS ELECTED JANUARY 13, 1922

ATHERTON, ALFRED LEROY, Section Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.

BURKHALTER, RUDOLPH, Division Superintendent, Southern Division, Public Service Company of New Jersey, 225 N. Warren St., Trenton, N. J.

CHITTY, A. M., Superintendent, Puget Sound International Railway & Power Co.; Superintendent, Light & Power, Pacific Northwest Traction Co.; res., 1401 Colby Ave., Everett, Wash.

HAMILTON, BRACE HAYDEN, Manager Power Division, Westinghouse Elec. & Mfg. Co., 803 Hibbs Bldg., Washington, D. C.

KLEINSCHMIDT, EDWARD E., President, Kleinschmidt Electric Company, 36 Flatbush Avenue Extension, Brooklyn, N. Y.

McKEEHAN, LOUIS WILLIAMS, Research Engineer, Western Electric Company, 463 West St., New York, N. Y.

PERRINE, JAMES OWEN, Dept. of Development & Research, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

QUIMBY, CLIFTON CLARK, District Plant Superintendent, American Tel. & Tel. Company, Boston; res., 6 Copeland Terrace, Malden, Mass.

WELLWOOD, ARTHUR RUSSELL, Engineer, Murray & Flood, 2041 Grand Central Terminal Bldg., New York, N. Y.

TRANSFERRED TO GRADE OF FELLOW, JANUARY 13, 1922

HILL, HALBERT P., Vice-President & General Manager, Ophuls, Hill & McCreery Inc., New York.

McCONAHEY, WILLIAM M., Manager, Transformer Engineering Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

TRANSFERRED TO GRADE OF MEMBER, JANUARY 13, 1922

BALLARD, FREDERICK W., Senior Member, F. W. Ballard & Co., Cleveland, Ohio

JACOBUS, ROBERT F., Partner, Francisco & Jacobus, New York, N. Y.

KISHLAR, LAMAR M., Electrical Engineer, Wagner Electric Mfg. Co., St. Louis, Mo.

MacNEILL, FRANCIS W., Sales Engineer, Canadian General Electric Co. Ltd., Vancouver, B. C.

MOON, FLOYD L., Electrical Engineer, Motor Engineering Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

SEAMAN, EDWIN H., Chief Engineer, Johnson & Higgins, New York, N. Y.

RECOMMENDED FOR TRANSFER

The Board of Examiners at its meeting held January 9, 1922, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Member

CAMP, WILMER E., Sales Engineer, General Electric Co., Sacramento, Calif.

CRITTENDEN, EUGENE C., Physicist, Acting Chief of Electrical Division, Bureau of Standards, Washington, D. C.

HARVEY, H. G., General Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

LASSAFF, B. W., Section Leader, New York Edison Co., New York, N. Y.

RANKIN, HARRY M., Lighting Engineering Dept., General Electric Co., Schenectady, N. Y.

SAMPSON, EDGAR R., General Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

SQUIRE, WILLIAM J., Consulting Engineer, Kansas City, Mo.

TOMPKINS, FREDERICK N., Instructor in Electrical Engineering, Brown University, Providence, R. I.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute, the list indicating the geographical district and Section in which the applicant is at present located. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before February 28, 1922.

Geographical District No. 1.

Boston Section

Damoiseau, Edward W., Boston, Mass.
Fleishmann, Edwin, Cambridge, Mass.
Hahn, Clifford A., (Member), Boston, Mass.
Moltedo, Louis P., Boston, Mass.

Connecticut Section

Borggrafe, Edward W., Stamford, Conn.
Hulse, George E., (Member), New Haven, Conn.
Shepherd, David G., (Member), Stamford, Conn.

Lynn Section

George, Bertrand L., Andover, Mass.
Glines, Roland B., Lawrence, Mass.
Kirk, Walter B., (Member), E. Lynn, Mass.
Poole, Herbert H., Portsmouth, N. H.

Providence Section

Kelley, Arthur M., New Bedford, Mass.
Putnam, John P., Providence, R. I.

Schenectady Section

Bish, Howard P., Schenectady, N. Y.
Buchanan, Harold F., Schenectady, N. Y.
Fosmire, Howard L., Schenectady, N. Y.
Hunt, Ozro H., Schenectady, N. Y.
Judkins, Ernest L., Schenectady, N. Y.
Leibing, Sidney C., Schenectady, N. Y.
Page, Harry S., Schenectady, N. Y.
Reitz, Harold J., Schenectady, N. Y.
Skolfield, William K., Schenectady, N. Y.
Sullivan, George L., Schenectady, N. Y.
Weaver, Albert, Schenectady, N. Y.

Worcester Section

Bigelow, Horace H., Worcester, Mass.
Budlong, Guy V., (Member), Worcester, Mass.
Coghlin, Peter A., (Member), Worcester, Mass.
Scott, Lorenzo J., Springfield, Mass.
Swift, George W., Springfield, Mass.

Non-Section Territory

Otto, Edmund G., Hill, N. H.
Priest, Conan A., Ellsworth, Maine
Roberts, Everett L., Bangor, Me.
Total 32.

Geographical District No. 2.

Baltimore Section

Hoffecker, Frank S., Sparrows Point, Md.

Cincinnati Section

De Camp, Herbert C., Dayton, Ohio
Matthieu, J. Clarence, Dayton, Ohio
Stewart, Edward N., Dayton, Ohio
Wente, Leslie H., Hamilton, Ohio
Wuichet, Richard P., Dayton, Ohio

Cleveland Section

Bartlett, Carroll A., Cleveland, Ohio
Keating, Leonard M., Mansfield, Ohio
Keiffer, Lawrence R., Nela Park, Cleveland, Ohio
Kositzky, Gustav A., (Member), Cleveland, Ohio
Scheu, Lester W., Cleveland, Ohio
Sears, Clarence G., Cleveland, Ohio

Erie Section

Hoag, Paul W., Erie, Pa.

Lehigh Valley Section

Hambleton, Joseph T., Pen Argyl, Pa.

Philadelphia Section

Hauer, Theodore M., Philadelphia, Pa.
Heller, William H., Pleasantville, N. J.
Riley, Weston K., Philadelphia, Pa.
Risko, William, Philadelphia, Pa.
Ward, Philip H., Jr., Philadelphia, Pa.

Pittsburgh Section

Harrington, George R., Scottdale, Pa.
Lerch, Charles W., E. Pittsburgh, Pa.
Piroth, Charles J., Pittsburgh, Pa.
Vazquez, Daniel A., Jr., Springdale, Pa.

Washington, D. C. Section

Page, Donald W., Washington, D. C.
Singleton, Louis W., Washington, D. C.

Non-Section Territory

Barksdale, John P., Charleston, W. Va.
Hoelle, Martin R., Hagerstown, Md.
Total 27

Geographical District No. 3.

New York Section

Beutter, Erwin G., New York, N. Y.
Borghard, A. W., Mt. Vernon, N. Y.
Brieger, Lawrence, New York, N. Y.
Brownley, Edward, Long Island City, N. Y.
Dannatt, Samuel H., New York, N. Y.
Davis, George E., New York, N. Y.
Eagin, John J., New York, N. Y.
Heger, Francis E., New York, N. Y.
Howard, Lawrence F., New York, N. Y.
Johnson, Oscar, New York, N. Y.
Keller, Arthur C., New York, N. Y.
King, Karl T., New York, N. Y.
Land, Edmund, New York, N. Y.
La Rosa, Leonard, New York, N. Y.
Lynam, Joseph P., New York, N. Y.
McAllister, Archibald, New York, N. Y.
Meier, Robert A., New York, N. Y.
Moody, Dwight L., New York, N. Y.
Neckerman, William G., New York, N. Y.
Nicely, Ralph N., (Member), New York, N. Y.
Pipes, Pliny P., New York, N. Y.
Ranger, Richard H., (Member), New York, N. Y.
Reed, Russell M., New York, N. Y.
Reidenbach, Alfred H., New York, N. Y.
Schabinger, Frederick, New York, N. Y.
Takasaki, Hitoshi, New York, N. Y.
Van der Poll, Jan A., New York, N. Y.
von Nostitz, Erich, New York, N. Y.

Non-Section Territory

de Tarnava, Constantino, Jr., Monterey, Mexico
Helvie, Roscoe S., Havana, Cuba
Total 30.

Geographical District No. 4

Atlanta Section

Daniell, Allie G., Atlanta, Ga.
Phillips, James E., Atlanta, Ga.

Non-Section Territory

Boyer, Garth C., Richmond, Va.
Curlee, Louis C., Birmingham, Ala.
Reid, Henry J. E., Hampton, Va.
Total 5.

Geographical District No. 5

Chicago Section

Andrews, Charles P., Great Lakes, Ill.
Bear, William P., (Member), Chicago, Ill.
Freyer, Arthur L., Hammond, Ind.
Jensen, Aage W. O., Chicago, Ill.
Stanfield, John H., Chicago, Ill.

Indianapolis-Lafayette Section

Stout, Fred H., Indianapolis, Ind.

Milwaukee Section

Hadley, Homer L., West Allis, Wis.
Lindner, Herbert G., Milwaukee, Wis.
Maguire, Francis A., Milwaukee, Wis.
Miller, Benjamin L., Milwaukee, Wis.
Schroeder, Gilbert W., Milwaukee, Wis.

Urbana Section

Howie, John L., Jr., Urbana, Ill.
Total 12.

Geographical District No. 6

Denver Section

Cawley, William H., Denver, Colo.
McCarn, George E., (Member), Denver, Colo.
Reading, William R., Denver, Colo.
Reed, Oliver P., Denver, Colo.

Omaha Section

Griswold, Phelps E., Omaha, Neb.
Gantt, Robert A., (Member), Omaha, Neb.

Minneapolis Section

Gaarden, Oscar, Minneapolis, Minn.
Manderfeld, Emanuel A., Minneapolis, Minn.
Peterson, Richard M., Minneapolis, Minn.
Purchas, Robert W. T., (Member), Minneapolis, Minn.
Streed, S. Martin, Minneapolis, Minn.
Young, Harold E., Minneapolis, Minn.

Non-Section Territory

Anderson, J. E., Maquoketa, Iowa
Monnich, Maurice J., Seward, Neb.
Soule, Martin H., Laramie, Wyo.
Triem, Ralph H., La Porte City, Iowa.
Total 16.

Geographical District No. 7

St. Louis Section

Hartman, Walter K., St. Louis, Mo.
Hauck, Louis W., St. Louis, Mo.
Hoagland, Lyman E., St. Louis, Mo.
LeMaster, William A., St. Louis, Mo.

Non-Section Territory

Deal, Harman B., Cape Girardeau, Mo.

Teague, W. L., Fayetteville, Ark.
Williamson, Carl H., Springfield, Mo.
Total 7.

Geographical District No. 8

Los Angeles Section

Hounsell, E. Victor, Los Angeles, Cal.
Spain, Carl J., Los Angeles, Cal.

San Francisco Section

Isaac, Rosa D., San Francisco, Cal.

Non-Section Territory

Keer, Edwin M., Tonopah, Nevada
Vaughan, Eleazer A., Lompoc, Cal.
Total 5.

Geographical District No. 9

Seattle Section

Greig, John W., Seattle, Wash.
Harrell, William F., Seattle, Wash.
Smith, Oliver C., Seattle, Wash.
Thompson, Earl A., Seattle, Wash.
Total 4.

Geographical District No. 10

Toronto Section

Allanson, Henry E., Toronto, Ont.
Allen, Charles H., Toronto, Ont.
Barthe, Cyril S., Toronto, Ont.
Kingstone, George A., Toronto, Ont.
O'Holloran, James, Toronto, Ont.

Non-Section Territory

Blakeborough, Harold A., Kelowna, B. C.
Bloomfield, James M., Calgary, Alta., Canada
Etches, Gerald D., Glace Bay, N. S.
Excell, Stephen H., Vernon, B. C.
McKeever, Frederick L., Penticton, B. C.
Raymond, Harold N., Montreal, P. Q.
Total 11.

Total Applications Received 149.

FOREIGN

Ayres, W. E. Milton, (Member), London, Eng.
Baarsrud, Knud, Kristiania, Norway
Inouye, Ikutaro, London, Eng.
Koike, Shigeo, Sukegawa, Ibarakiken, Japan
Kusumoto, Sojiro, Sukegawa, Ibarakiken, Japan
McCracken, Glenn W., Santiago, Chile
Natarajan, R., Bombay, India
Nishi, Eisuke, Sukegawa, Ibarakiken, Japan
Ohnishi, Sadahiko, Sukegawa, Ibarakiken, Japan
Okuwa, Satoru, Sukegawa, Ibarakiken, Japan
Semmens, Clive T. K., Rugby, Eng.
Skinker, Murray F., Oxford, Eng.
Souza, Manual E., Sao Paulo, Brazil, S. A.
Tokai, Shinzo, Sukegawa, Ibarakiken, Japan
Yokoi, Nobuyoshi, Sukegawa, Ibarakiken, Japan
Total 15.

STUDENTS ENROLLED JANUARY 13, 1922

14283 Burkhardt, Christian E., University of Wis.
14284 Bunyan, George A., Worcester Polytechnic Institute
14285 Rohrdanz, Edwin, Lewis Institute
14286 Robinson, Willard M. L., Cornell Univ.
14287 Carr, Edward H., Cornell University
14288 Potter, Marcus L., Jr., Purdue University
14289 Deming, Herschel P., Purdue University
14290 Hendrickson, Ernest R., Purdue University
14291 Ahmed, S. H., Purdue University
14292 Faris, Arthur W., Purdue University
14293 Knowles, D. D., Purdue University
14294 Bement, David L., Purdue University
14295 Marzulli, Angelo M., Purdue University
14296 Stewart, Rollin H., Purdue University
14297 Sharma, G. C., Purdue University
14298 Thomas, Earl R., Mass. Inst. of Tech.
14299 McKinley, Thomas W., Drexel Institute
14300 Davee, Lawrence W., University of Maine
14301 Knowles, Frederick L., Carnegie Inst. of Technology
14302 Mohr, Ernst J., University of Wisconsin
14303 Alden, Philip M., Mass. Institute of Tech.
14304 Coupland, Robert R., Toronto Central Technical School
14305 Melcher, Harvey R., University of Wis.
14306 Stribling, Thomas T., N. Y. Elec. School
14307 Beckley, James E., Drexel Institute
14308 Beebe, Henry J., Drexel Institute
14309 Brinsfield, Allen M., Drexel Institute
14310 Cordes, Charles M., Drexel Institute
14311 Devine, John J. A., Drexel Institute
14312 Doughty, Herbert C., Drexel Institute
14313 Fury, William M., Drexel Institute
14314 Gannon, James J., Drexel Institute
14315 Graham, Charles H., Drexel Institute
14316 Henry, John J., Drexel Institute
14317 Henry, Paul H., Drexel Institute
14318 Jellenhaus, Norman K., Drexel Institute
14319 Koch, William B., Drexel Institute
14320 Leeds, Louis E., Drexel Institute
14321 Light, Edwin D., Drexel Institute
14322 Logue, Michael J., Drexel Institute
14323 Ludwig, Allen K., Drexel Institute
14324 Naudain, Willis A., Drexel Institute
14325 Neuber, Samuel T., Drexel Institute
14326 Petrov, Morris, Drexel Institute
14327 Samson, Edward L., Drexel Institute
14328 Shields, Dennis J., Drexel Institute
14329 Stevens, Carl J., Drexel Institute
14330 Stevens, W. G., Jr., Drexel Institute
14331 Thompson, John, Drexel Institute
14332 Tyson, James S., Jr., Drexel Institute
14333 Whitman, Stanley H., Drexel Institute
14334 Brookes, Kenneson H., Univ. of Calif.
14335 Robertson, Lawrence M., Univ. of Colo.
14336 Nile, Jack, Newark Technical College
14337 Gray, Wallace G., Toronto Central Technical School
14338 Ward, Charles, Toronto Central Technical School
14339 Saube, Nicholas C., Drexel Institute
14340 Kenworthy, Joseph W., Drexel Institute
14341 Clark, John J., Drexel Institute
14342 Kasonof, Morris, Drexel Institute
14343 Jennings, George A., Kansas State Agr. College
14344 Hickernell, Latimer F., Mass. Inst. of Tech.
14345 King, George W., Mass. Inst. of Tech.
14346 Garber, Leslie Harold, University of Wis.
14347 Garrett, Russell A., Purdue University
14348 Holaday, Frank M., Purdue University
14349 Cook, Thomas J., Purdue University
14350 Bledsoe, Cecil L., Purdue University
14351 Yiin, Gabriel Chen, University of Wis.
14352 Olson, Joseph B., Lewis Institute
14353 Keno, Meyer L., Lewis Institute
14354 Layne, Laurence E., Lewis Institute
14355 Jones, Elmer C., Lewis Institute
14356 Bishop, Wallace V., University of Toronto
14357 Zahour, Robert L., Case School of Applied Science
14358 Mead, Milton S., Jr., Case School of Applied Science
14359 Jung, Michael J., Case School of Applied Science
14360 Raczynski, Louis, Lewis Institute
14361 Shrader, Dow T., Lewis Institute
14362 Kiefer, Michael J., Lewis Institute
14363 Gilbert, Ralph H., Mass. Inst. of Tech.
14364 Shields, Stanley O., University of Toronto
14365 Shu, Chu, New York Electrical School
14366 Bennett, L. Earle, Drexel Institute
14367 Shew, C. Barrett, Drexel Institute
14368 Farber, Harry M., Drexel Institute
14369 Salnen, George C., Drexel Institute
14370 Zeitz, Edwin R., Yale University
14371 Monk, Newton, Harvard University
14372 Bateman, J. W., University of Toronto
14373 Blanch, Frederick D., University of Wis.
14374 Cerries, Louis, New York Electrical School
14375 Mueller, William A., Univ. of Nebraska
14376 Haller, Charles J., University of Illinois
14377 Nash, Russell O., University of Minnesota
14378 Schow, Garfield G., University of Minn.
14379 Scott, Herbert L., University of Minn.
14380 Zimmerschied, Clarence R., Univ. of Minn.
14381 Kimball, George K., 3rd, Colorado State Agricultural College
14382 Hall, Thomas M., Colorado State Agricultural College
14383 Ayres, A. Frank, Colorado State Agri. College
14384 Borschell, Edson J., Colorado State Agri College
14385 Lang, Gerald F., Colorado State Agri. Coll.
14386 Peter, Harold O., Colorado State Agri. Coll.
14387 Deggett, Gilman C., Colorado State Agri. College
14388 Wadsworth, John J., Colorado State Agri. College
14389 Lee, Robert J., University of Washington
14390 Chilberg, Elmer N., University of Wash.
14391 Rathbun, John H., University of Wash.
14392 Bergstrom, Theo., University of Wash.
14393 Stevens, Richard F., University of Wash.
14394 Bell, Robert C., Univ. of Southern Calif.
14395 Caldwell, Duncan K., University of Southern California
14396 Cockfield, Robert H., University of Southern California
14397 Heath, Edward B., University of Southern California
14398 Hess, James G., University of Southern California
14399 Hichborn, Donald B., Univ. of Southern California
14400 Howes, E., Univ. of Southern Calif.
14401 Landers, Challen F., Univ. of Southern California
14402 Robb, Marson S., Univ. of Southern Calif.
14403 Schiller, George, Univ. of Southern Calif.
14404 Sauerman, E. Walter, Univ. of Southern Calif.
14405 Summers, H. Julien, Univ. of Southern California
14406 Zahn, Arthur W., Univ. of Southern Calif.
14407 Cook, Albert W., Univ. of North Dakota
14408 Bydal, Clarence B., Univ. of North Dakota
14409 Dunlevy, Jerome N., Univ. of North Carolina
14410 Ebenhahn, Alfred W., Univ. of North Dakota
14411 Goehl, Arthur H., Univ. of North Dakota
14412 Hough, Eugene L., Univ. of North Dakota
14413 Langlord, Alfonso M., Univ. of North Dak.
14414 McLean, Donald H., Univ. of North Dak.
14415 Nogosek, Stephen J., Univ. of North Dak.
14416 Rudiselle, Theodore E., University of North Dakota
14417 Smeby, Rudolph P., Univ. of North Dak.
14418 Winji, Severt W., Univ. of North Dak.
14419 Witmer, Robert B., Univ. of North Dak.
14420 Williamson, Robert J., Univ. of Toronto
14421 Teeple, Ralph J., Armour Inst. of Tech.
14422 MacLellan, University of Toronto
14423 Allen, Richard D. S., Drexel Institute
14424 Khalifah, A. Zaki Amer, Drexel Institute
14425 Diehl, Edward A. P., Drexel Institute
14426 Johnson, Norman F., Univ. of Toronto
14427 Senior, Arthur H., Ohio Northern Univ.
14428 Jaques, Clarence A., Univ. of Toronto
14429 Gray, Albert S., University of Toronto
14430 Olsen, Elvin E., Michigan Agri. College
14431 Agnor, Gilmore L., Virginia Military Inst.
14432 Ames, Walter C., Jr., Virginia Military Institute
14433 Archer, William W., Jr., Virginia Military Institute
14434 Carter, Robert G., Virginia Military Inst.
14435 Connally, Marshall H., Virginia Military Institute
14436 Glazier, Sam, Virginia Military Institute
14437 Marshall, Wilson C., Virginia Military Inst.
14438 Martin, Robert W. P., Virginia Military Institute
14439 Moore, Joseph P., Virginia Military Inst.
14440 O'Brien, William V., Virginia Military Inst.
14441 Pennybacker, Meade W., Virginia Military Institute
14442 Rainey, Thomas C., Virginia Military Inst.
14443 Shannon, William V., Virginia Military Institute
14444 Venable, William P., Jr., Virginia Military Institute
14445 Wilson, Harry W., Virginia Military Inst.
14446 Jaffey, Robert J., Virginia Military Inst.
14447 Buch, G. R., Virginia Military Institute
14448 Shackelford, Augustus G., Virginia Military Institute
14449 Carroll, Eugene L., Jr., Va. Military Inst.
14450 Crenshaw, Arcger D., Va. Military Inst.
14451 Hubard, Tazewell T., Va. Military Inst.
14452 Johnson, John O., Virginia Military Inst.

14453 Patterson, William A., Va. Military Inst.
14454 Robertson, Walter G., Va. Military Inst.
14455 Sollers, Basil F., Johns Hopkins University
14456 Thomas, David D., Jr., Hohns Hopkins University
14457 Egert, C. L., Johns Hopkins University
14458 Porter, James F., Johns Hopkins Univ.
14459 Dougherty, Harry, Jr., A. & M. College of Texas
14460 Luecke, Carl L., University of Kansas
14461 Short, Albert L., University of Kansas
14462 Hanlon, Harry W., University of Kansas
14463 McLean, Gordon E., University of Kansas
14464 Burns, David, University of Toronto
14465 Nablo, Harold W., University of Toronto
14466 Koopmann, John J., Clemson Agri. Coll.
14467 D'Hooghe, Eugene, Stanford University
14468 Barland, George C. G., Univ. of Wis.
14469 Grelick, David, Mass. Inst. of Technology
14470 Erickson, Edward H., Rutgers College
14471 Butler, Edward J., Rutgers College
14472 Grant, Ulysses S., Tri-State College of Engineering
14473 Goetz, Fred E., University of Wisconsin
14474 Lunda, Ernest M., University of Wisconsin
14475 Fisher, Ralph D., Armour Inst. of Tech.
14476 Trow, Luther S., Wentworth Institute
14477 Sexton, Seymour, University of Nebraska
14478 Davis, Kirk E., Clarkson Coll. of Tech.
14479 Hentz, Clifford E., Lowell Institute
14480 Buehl, Louis H., Jr., Drexel Institute
14481 West, Frederick P., University of Virginia
14482 Bauserman, Harry F., University of Va.
14483 Murphy, T. Henry, University of Virginia
14484 Glick, Justus E., University of Virginia
14485 Kater, Joseph A., University of Virginia
14486 Morgan, Marrion H., Jr., Univ. of Va.
14487 Murphy, James K., University of Virginia
14488 Parrack, Vasco R., University of Virginia
14489 Rawls, Reuben R., University of Virginia
14490 Thompson, Robert J., Univ. of Toronto
14491 Johnston, Bruce H., University of Toronto
14492 Bergen, Howard B., Lehigh University
14493 Anderson, Charles E., Vir. Military Inst.
14494 Little, Daniel C., Virginia Military Inst.
14495 Evans, Meyler G., University of Toronto
14496 Benson, Wilfred R., University of Toronto
14497 Cady, Dewey, University of North Dakota
14498 Hill, Byron R., University of North Dakota
14499 Myhre, Conrad B., Univ. of North Dakota
14500 Howden, Harold E., University of Toronto
14501 Wood, Albion R., Mass. Inst. of Tech.
14502 Carrington, Edward L., Worcester Polytechnic Institute
14503 Stann, Harry W., Cooper Union
14504 Johsson, Nils F., Drexel Institute
14505 Taylor, Merton L., Clarkson Coll. of Tech.
14506 Goodhue, B. C., Syracuse University
14507 Tecter, John H., Mass. Institute of Tech.
14508 Glou, Harry C., Penn. State College
14509 Taylor, William B., Clarkson Coll. of Tech.
14510 Fulton, Richard B., Johns Hopkins Univ.
14511 Pedder, James F., University of Toronto
14512 Lothrop, Esmond F., Wentworth Institute
14513 Diefenbach, Lowell T., Univ. of Cincinnati
14514 Ridout, Geoffrey S., University of Toronto
14515 White, Richard E., University of Toronto
14516 Kent, Harry E., Mass. Inst. of Tech.
14517 Thompson, Francis R., Carnegie Inst. of Technology
14518 Nordstedt, Einar A., University of Wis.
14519 Diffendaffer, Joseph A., Cass Technical High School
14520 Leggett, John A., Lowell Inst. School for Industrial Foreman
14521 Wells, Nathaniel D., Lowell Inst. for Industrial Foreman
14522 Baird, Harry P., University of Toronto
14523 Dalphin, Robert, Clarkson Coll. of Tech.
14524 Smith, J. Burnham, Mass. Inst. of Tech.
14525 Elliott, Frank W., University of Toronto
14526 Megargee, Nathan L., Colo. Agri. College
14527 Minnium, Byron B., University of Cin.
14528 Schaffer, Harry E., Bucknell University
14529 Clark, Chester N., University of Illinois
14530 Scott, Wayne Le Roy, Penn. State College
14531 Reilly, James W., Wentworth Institute
14532 Woolley, Horace W., Toronto Central Technical School
14533 Eastwood, D. Ross, Toronto Central Technical School
14534 Mann, Muse E., Clemson Agri. College
14535 Roth, Victor T., Jr., Drexel Institute
14536 Ross, Alexander D., Mass Inst. of Tech.
14537 Wich, John F., Stevens Inst. of Tech.
14538 Moore, George A., Lafayette College
14539 Hogue, Leland J., University of Illinois
14540 Myers, Walter H., N. Y. Electrical School

Total 258.

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William McClellan

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A. W. Berresford

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A. I. E. E. COMMITTEES

(A list of the personnel of Institute committees may be found in the January issue of the Journal, and will be published again in the June issue.)

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Finance, L. F. Morehouse
Meetings and Papers, E. E. F. Creighton
Publication, A. S. McAllister
Coordination of Institute Activities, W. I. Slichter
Board of Examiners, H. H. Norris
Sections, A. W. Berresford
Student Branches, C. Francis Harding
Membership, E. H. Martindale
Headquarters, W. A. Del Mar
Law, H. H. Barnes, Jr.
Public Policy, H. W. Buck
Code of Principles of Professional Conduct, C. A. Adams
Safety Codes, H. B. Gear
Standards, Harold Pender
Edison Medal, C. A. Adams
Research, F. B. Jewett

TECHNICAL COMMITTEES AND CHAIRMEN

Educational, C. E. Magnusson
Electrical Machinery, B. A. Behrend
Electrochemistry and Electrometallurgy, Lawrence Addicks.
Electrophysics, F. W. Peek, Jr.
Industrial and Domestic Power, W. C. Yates
Instruments and Measurements, F. V. Magalhaes
Iron and Steel Industry, E. S. Jefferies
Lighting and Illumination, G. H. Stickney
Marine, Arthur Parker
Mines, Graham Bright
Power Stations, R. F. Schuchardt
Protective Devices, H. R. Woodrow
Telegraphy and Telephony, Donald McNicol
Traction and Transportation, H. M. Brinckerhoff
Transmission and Distribution, Edward B. Meyer

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(The Institute is represented on the following bodies; the names of the representatives may be found in the January issue of the Journal and will be published again in the June issue.)

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American Bureau of Welding
American Committee on Electrolysis
American Engineering Council of the Federated American Engineering Societies
American Engineering Standards Committee
Board of Trustees, United Engineering Society
Engineering Foundation Board
Franco-American Engineering Committee
John Fritz Medal Board of Award
Library Board, United Engineering Society
Electrical Committee, National Fire Protection Association
Engineering Division, National Research Council
U. S. National Committee of the International Illumination Commission
U. S. National Committee of the International Electrotechnical Commission
Commission of Washington Award

A. I. E. E. SECTIONS AND BRANCHES

A complete list of the 42 Sections and the 67 Student Branches of the Institute, with the names of the chairmen and secretaries, may be found in the January issue and will be published again in the June issue.

DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGS AND OTHER TRADE PUBLICATIONS

Mailed to interested readers by issuing companies.

Recording Electrical Instruments.—Catalog 1501, 31 pp. Describes recording voltmeters, ammeters, wattmeters, millivoltmeters, shunt ammeters, frequency meters, etc. The Bristol Company, Waterbury Conn.

Electrical Protecting Materials and Conduit Fittings.—Catalog 29, 96 pp. Renewable and non-renewable fuses, wire and metal links, switch and outlet boxes, extension rings, etc. Chicago Fuse Co., Laflin & 15th Sts., Chicago.

Marine Equipment.—Circular 106, 17 pp. Describing geared turbine propulsion, Diesel electric propulsion, deck auxiliaries, generating sets and auxiliaries, dry dock and shipyard equipment, arc welding. Westinghouse Elec. & Mfg. Co., East Pittsburgh.

Photometers.—Catalog No. 32. Spherical photometers and Sharp-Millar portable photometers, for measuring lumens or mean spherical candlepower of incandescent lamps. Foote, Pierson & Co., Inc., 160 Duane St., New York.

Outdoor Substations.—Bulletin 37, 64 pp. Illustrates installations of outdoor substations and accessory equipment, switches, arresters, choke coils, etc. Delta-Star Electric Co., 2433 Fulton St., Chicago.

Time Switches.—Bulletin, 9 pp. Describes operation and attachments of Sauter time switches, including astronomic dial, Sunday cut-out, additional poles on revolving switch, remote control, etc. R. W. Cramer & Co., 136 Liberty St., New York.

Vertical WaterWheel-Driven Generators.—Circular 3439, 4 pp. Westinghouse Elec. & Mfg. Co., East Pittsburgh.

Combustion Problems.—Bulletin 220, 7 pp. "Magnitude of the Power Plant's Chimney Loss," and Bulletin 221, 11 pp. "Relation between $C\,O_2$ and Money Wasted up the Chimney"; illustrating the saving claimed by use of Recording Equipment. Uehling Instrument Co., Paterson, N. J.

Polyphase Motor.—Bulletin 129, 12 pp. Describing the new "Pow-R-full" polyphase motor. Wagner Elec. Mfg. Co., St. Louis.

Wire Rope.—Book,137pp.,"Outspinning the Spider." A history of wire rope manufacture. Describes the wire rope barrage installed in the English Channel during the late war, the Brooklyn Bridge and other notable applications of wire-rope. John A. Roeblings' Sons Co., Trenton, N. J.

Electrical Brushes.—Catalog 7, 48 pp. Describes characteristics of various types and applications. Contains price-list. Corliss Carbon Co., Bradford, Pa.

Wiring Devices.—Catalog, 304 pp., leather covered, pocket size. Sockets, switches, fuses, receptacles, etc. The Connecticut Electric Mfg. Co., Bridgeport, Conn.

Circuit Breakers.—Bulletin, 36 pp. Describing the "U-Re-Lite" circuit-breaker and applications in industrial plants. The Cutter Company, Philadelphia.

Turbine Steam Generator Units. Circular 1094-B, 36 pp. Discusses reactance and impulse types, both semi-double flow type and multiple cylinder type. Bleeder turbines and geared turbines are described, as well as the generator. Westinghouse Elec. & Mfg. Co., East Pittsburgh.

Freight Handling Device.—Bulletin, 12 pp. Contains specifications of Viche Safety Toe Board, made of pressed steel, which is claimed to be particularly suitable for loading heavy electrical machinery from platforms to freight cars, and vice-versa. L. C. Eitzen Organization, 280 Broadway, New York.

Refractory Linings.—Bulletin, 18 pp. "Hytempite in the Power Plant." Describes the applications of Hytempite (a refractory material) for bonding fire brick and kindred uses. Quigley Furnace Specialties Co., 26 Cortlandt St., New York.

Laboratory and Commercial Electrical Accessories.—Bulletin 18, 15 pp. Carbon Compression Rheostats; D. C. Meter Loading Units, including Edison Storage Cells; Single and Triplex Plug Terminal Lugs; Meliorate Solderless Terminals; Thumbar Terminals Binding Posts and Connectors, etc. Standard Scientific Co., West 4th & Barrow Sts., New York.

Commutator Resurfacers.—Leaflet, describing "Ideal" commutator resurfacers. Ideal Commutator Dresser Co., Chicago.

Waterwheels.—Bulletin 17, 48 pp. Describes impulse and reaction turbines and accessory equipment. Pelton Water Wheel Co., San Francisco.

Safety Switches and Panel Boards.—Catalog 12-A, 64 pp. Westinghouse Elec. & Mfg. Co., East Pittsburgh.

Dynamometer.—Bulletin 48716, 8 pp. Apparatus for accurate measurement of torque or power. Sprague Electric Works of G. E. Co., 527 W. 34th St., New York

Vacuum Pump. Bulletin 92, 4 pp., "New Rotary Cenco Hyvac Pump." Production of a vacuum of 0.001 mm., without a preliminary or backing pump, is claimed for this apparatus. Central Scientific Co., 460 E. Ohio St., Chicago.

Balancing Machines.—Bulletin. Olsen-Carwen Static-Dynamic Balancing Machines, for detecting and indicating the exact point causing unbalance in the rotors of high speed machinery such as motors, turbines, etc. Tinius Olsen Testing Machine Co., 500 No. 12th St., Philadelphia.

MISCELLANEOUS

Standard Underground Cab e Co.—Atlee B. Saurman has been appointed General Sales Manager with headquarters in Pittsburgh. Mr. Saurman has been connected with the company over twenty years, as manager of the Boston, San Francisco, and until recently, the Philadelphia offices. Edward Kerschner has been appointed manager of the new Southeastern Sales Dept. with headquarters in Washington, D. C. He has been with the company for many years, in the Pittsburgh, Philadelphia and Washington offices. F. O. Hoyt has been appointed manager of the Philadelphia Sales Dept.

Cutler-Hammer Mfg. Co.—The Boston office has moved to 404 Harvey Bldg., Chancy St. This branch is in charge of C. W. Yerger.

American Fibre Conduit Corporation. E. J. O'Neil former manager of the Chicago office, which is no longer maintained, has been made Business Manager of the company, at the Executive Offices in Fulton, N. Y. Communications should be addressed to the General Sales Office, 103 Park Ave., New York, or to the nearest branch of the Western Electric Co., sole distributors in the United States.

The Cutter Co.—Circuit breakers and switches, Philadelphia. The Toronto Office has recently been re-opened, in charge of Donald M. Fraser, at 24 Adelaide St., East. Mr. Fraser was formerly connected with the Canadian General Electric Co.

The Roller-Smith Company.—Electrical instruments and circuit breakers, New York. O. I. Eberhardt, Board of Trade Bldg., Scranton, Pa., has been appointed special representative to handle this company's line in a number of Pennsylvania counties.

Geo. J. Kirkgasser & Co.—Advertising. H. B. Price, formerly advertising manager of the Belden Mfg. Co., is now connected with Kirkgasser agency and will specialize in electrical and technical advertising.